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AND

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PRODUCTION OF OIL FROM CANNEL COAL
AND ALLIED MINERALS.

## CONTENTS.


PAGE

Council and Officers ... ... ... ... ... ... i

Committees ... ... ... ... ... ... ... ii

General Notices:—

Copyright ... ... ... ... ... ... ... iv

Issue of Journal ... ... ... ... ... ... iv

Changes of Address ... ... ... ... ... iv

To Authors of Papers ... ... ... ... ... iv

The Library ... ... ... ... ... ... v

List of Exchanges ... ... ... ... ... viii

Advertisements in the Journal ... ... ... ... x

List of Advertisers ... ... ... ... ... x

Personal Notes of Members ... ... ... ... ... x

Editorial:—How to Help the Institution ... ... ... 105

(Twenty-sixth General Meeting, 18th October, 1917):—

*Postponed Discussion* on The Prospective Oilfields of Barbados, by Messrs. I. A. Stigand and E. H. C. Craig ... ... ... ... ... ... .. 107

Twenty-eighth General Meeting, 19th February, 1918:—

*Papers* (3): A New British Oil Industry, by E. H. C. Craig, B.A., F.R.S.E., F.G.S.: Dr. F. M. Perkin, F.I.C., F.C.S.: A. G. V. Berry: and Dr. A. E. Dunstan, F.I.C., F.C.S. ... ... ... ... 110

*Discussion:* by the President, D. V. Hollingworth, H. T. Burls, Sir Boverton Redwood, — Hill, A. E. M. Taylor, J. Todd, R. Bowen, F. Lamplough, Prof. J. Cadman, W. H. Manfield, and Sir Lionel Phillips ... ... ... ... ... ... ... 134

Twenty-ninth General Meeting, 19th March, 1918:—

*Paper:* The Russian Petroleum Industry and its Prospects, by D. Ghambashidze, Hon. Sec. and Exec. Councillor of the Russo-British Chamber of Commerce in London ... ... ... ... ... ... 158

*Discussion:* by Sir Boverton Redwood (Chair), C. B. Rosenplaenter, and R. J. Ward ... ... ... 184

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## Additions to the Library.

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Abel, F. A. [Presidential] Address. *Rep. Brit. Assoc.*, 1890, pp. 3–51. (Exc.)
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*From Sir Boverton Redwood.*

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*From the Board.*

SHIPBUILDING AND SHIPPING RECORD, Feb. 28–April 25, 1918.
*By Exchange.*

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*From C. B. Rosenplaenter.*

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Society of Chemical Industry.
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## PERSONAL NOTES OF MEMBERS AND SPECIAL NOTICES.

*It is suggested that Members of the Institution send information regarding their movements to the Secretary for insertion under this heading*

Mr. A. Lloyd Eastlake has been promoted to be full Lieutenant, and is now attached to Special Brigade, R.E., Devonport.

Mr. G. W. Halse is engaged in investigating the oil possibilities in Mesopotamia.

Dr. J. A. Leo Henderson returned to England in March from Trinidad, via Canada.

Mr. F. G. Rappoport has joined the Indian Army Reserve of Officers, and been posted for Active Service as a 2nd Lieutenant to the Royal Engineers.

The sending of Journals to members in Russia, owing to existing circumstances prevailing there, is postponed for the present, but will be resumed as soon as possible. Back numbers of the Journal, from Part 13, are being reserved for members temporarily living in that country.

## EDITORIAL.

**How to help the Institution.**

In our last issue we appealed to our members for more assistance in carrying on the work of the Institution in the various ways in which such participation may be possible to each individual member. It has been suggested by the Hon. Secretary that on the present occasion more specific indication might be proffered, in a classification of the many different forms such assistance may take.

Participation in administration and in the work of Committees, in the discussions at our meetings or subsequently, the advocacy to non-members of the advantages of union, and the communication of minor pieces of information which may be of interest (and no harm is done if they are not so), and other ways of promoting the utility of the Institution, can only be recommended, as has already been done, in broad general terms, but for the more detailed subdivisions of our wide-ranging subject the following summary may be suggestive, alike to students and seniors, of such points as, coming within individual experience, might be the basis of communications of advantage to the Institution.

Starting with the raw material of our subject—oil already formed, or potential in oil-shales, etc.—we have already published in our four volumes papers dealing on broad lines of general description with several fields of production, viz., in Trinidad, Western Canada, Kansas and Oklahoma, Mexico, Uralsk, British Isles, Assam, Barbados, Rumania and Russia. Many others await similar general handling :—Galicia, Burma, Persia, Peru, Venezuela, the Dutch East Indies, Australia, the Argentine, the several widely different regions of the United States, and so on.

For each of these, and for others, detailed accounts of the geology, mode of operation, chemistry of refining, mining laws and regulations, and other subdivisions, would be most useful.

We have had also general papers on anticlinal geometry, on the principles of geological mapping, on kerogen shales and on natural gas. To these may be added, in the future, articles on the original formation of petroleum, the relations of its several inherent or adventitious constituents, the advantages or otherwise of State proprietorship of minerals, fluid or solid, and like world-wide topics.

On the technological side also, we have had several subjects handled in masterly style, summaries, in their respective departments, of matter that could advantageously be extended to large

volumes, and should be the basis of many papers as evolution continues. General equipment, field engineering, refining, storage, ocean transport, and modes of utilisation have been thus treated of, and in a few cases more detailed accounts have been set forth, as on the most advantageous forms of power in the field, pyrogenetics and viscometry in and beyond the refinery, the sulphur and toluene questions. To this brief list may well be anticipated the addition of many other technological articles such as, in the field, the keeping of proper logs (with, if such be possible, a standard form), the improvement practicable in fuller extraction of oil from its underground reservoirs, the principles to be observed in pipe-line construction and operation, etc.; and in the refinery, the replacement of the drastic treatment with sulphuric acid by some alternative process (a problem which appears to have been but partially solved by the use of bauxite), whilst other points in which fuller grasp is desirable of the essential conditions will suggest themselves to students who may have leisure to investigate them.

The cry for standardisation comes from every department of technological science, and many of these come within the purview of the Institution. In the selection of plant for field, refinery or transport and of apparatus for the laboratory, in the systematic method of operation and of record of the results in each of these, standardisation, if not the absolute panacea which some extremist advocates seem to consider it, has been of enormous advantage where adopted, and is capable of vast extension. We may on some future occasion deal more fully with this topic than space permits at present, but it is one which might well constitute the subject of a series of papers, general and special.

As to save is to gain, the right use of lubricants in at least reducing the futile expenditure of energy, is a duty incumbent on all who have to do with machinery, and the selection, preparation, judicious use and recovery of lubricants have been partially dealt with in our pages, but there yet remains much to do in investigation, both as to the chemical and physical essentials of materials used in lubrication, the methods of application, the economic effect, and in some cases the recovery and renewal of utility. Here again is the topic for a long series of papers, the wide diversity of purpose demanding in each case the adjustment of means to aim which is the basis of success in any operation.

Finally, our main need being facts, we repeat YOUNG'S counsel to

> "Think naught a trifle, though it small appear,
> Small sands the mountain, moments make the year,
> And rifles, life."

## The Prospective Oilfields of Barbados.

**Mr. I. A. Stigand** thus opens a discussion on Mr. Craig's paper, see p. 68:—

Mr. Craig's paper is of much interest and importance, especially in regard to the general tectonic considerations of the Caribbean region, and suggests a few questions.

First, the view that the Caribbean sea is described by a recent earth-fold of great magnitude would appear to be confronted with considerable difficulties, more especially in making the varied formations of the West Indies, which require more local and complex oscillations or movements, conform to an arrangement of this nature. Under any such general hypothesis it would be difficult to account for the aspects of the older Caribbean formation as well as the Tertiary sedimentary deposits of the Leeward Islands. The Caribbean series, in Venezuela and Trinidad, presents every appearance of an old land-surface, which has been, and possibly still is, in the course of secular subsidence, perhaps intermitted by some minor oscillations, a supposition further suggested by the absence of outliers, except in some low positions as at the extremity of Tobago.

It would seem, for the purposes of general study of the physical history of the region, that while Trinidad, in view of a certain similarity and continuance of the salient features, may be best considered in relation to the mainland, of which it is but a more complicated corner, the conditions in the Lesser Antilles would, in the absence of better propositions, be best explained by the Antillean dislocation suggested by Mr. Guppy. Although it may generally be desirable to deprecate the introduction of cataclysmal causes, there is considerable support of this view to be found in the arrangement of the sedimentary islands of the Leeward group, and the relations of the sedimentary to the volcanic deposits in the islands of Guadeloupe and Antigua, though it is difficult to see the reasons for prolonging this fault through the Bocas. As far as the Greater Antilles are concerned, that region would probably belong to another category and succession of movements. It is mentioned that in Barbuda the Recent Coral formation obscures all trace of older strata, but Middle Tertiary fossils from there were described by Duncan and Guppy, the latter regarding them as of Miocene age, and some beds there have been compared with the Antigua calcareous series (of the lowest Miocene), or it is possible that the other islands to the north-west (Anguilla, St. Barts, St. Martin, etc.) may be of similar age. The Tertiary strata in

Antigua are much less highly folded than those in Barbados or Trinidad; and it is observable in the East Indies also that less highly folded and disturbed conditions obtain locally in the neighbourhood of volcanic activity.

With reference to the same trough or depression as affected Barbados extending also to Trinidad, I understand that the Oceanic deposits of Barbados belong to the latest Tertiary, and, from what palæontological evidence has been recorded, are probably not earlier than Pliocene, whereas the deep-sea deposits in Trinidad should be somewhat earlier. Moreover, the regions would have been separated by the extensive range of the Caribbean series—besides the pre-Tertiary core dividing the northern and southern Tertiary basins in Trinidad. More synchronous should have been the deposition of the upper arenaceous series of Trinidad, which attain to so great a thickness, and imply rapid deposition on a shallow and slowly-sinking bottom.

Regarding the origin of the materials forming the Scotland beds—for which the previous existence of a neighbouring land-surface is of course a necessity—the land suggested to the south and east is presumably the proposed "Atlantis," but might not the former land-mass of the Caribbean series, of Trinidad and Tobago, have provided a possible origin? This must have formerly extended far to the north-east, and have been an elevated land-mass of considerable breadth, as suggested by the present contour of the sea-bottom, termed by Guppy the Parian sub-continent.

Turning to oil-prospects in Barbados, the highly-folded and disturbed nature of the petroliferous series would appear to the casual observer to present about the most unfavourable conditions imaginable for paying exploitation. Here, the strata have been folded and twisted in every manner and direction, resembling the convoluted structure of a miniature mountain-system, and even fan-structure on the small scale is observable in places. Under such conditions the structure at depth cannot be anticipated to be similar to that seen on the surface. Moreover, the relations of the older series to the Oceanic beds, and the apparent uniformity and configuration of the base of the latter, suggest that the former may have been reduced to a base-level of erosion, and thus long exposed to denudation and facilities for escape. It does not seem as if the post-Oceanic flexures could be of much consequence, since they cannot be expected to find accordance in the intensely-folded Scotland series, and apparently the Oceanic beds are lithologically unfavourable, and do not occur in alternations

suited for concentration; again, the bulk of the latter series (as far as I know) seems to be composed of the porous marls, the clays being found at the top, in which case these strata would not be very effective in sealing up petroliferous portions of the underlying beds. With reference to tracing the folds underneath, or drilling through the Coral limestone, this would seem like trying to hit a target which cannot be seen and may not be present at all; whilst the water which is likely to be encountered at the base of the limestone might much increase the cost of testing. It would seem that remunerative drilling could only be likely in Barbados by cheap wells, and provided that oil of exceptionally high grade were to be found.

I have not, however, had opportunity of seeing anything in the region of the more southerly exposures. At the time of my visit, two wells—as far as I could gather—were still being baled about once a week at Turners Hall, while at Lloyd's Oil Wells there is still some exudation of a tarry petroleum. In the vicinity of the former locality some emanations of gas were to be observed, but the so-called "boiling spring" is apparently now extinct.

**Mr. Craig** replies as follows:—

Mr. Stigand's remarks are very interesting, and it is unfortunate that the paper was not read, as the whole subject of the tectonics of the region could have been discussed with the diagrams and maps, which would have enabled the relations of each separate area to be made clear.

I have frequently discussed the subject with the late Mr. Guppy, and there was but little divergence in our views, except that the volcanic line of weakness, probably a faulted anticline, does not pass through the Bocas, but curves round to Margharita in conformity with the general structure.

The Oceanic beds of Barbados represent a long interval of time. Of fossils of Pliocene age recorded from them, most, I believe, come from a deposit which has since been proved not to belong to the Oceanic series at all. The marl beds in Trinidad come fairly high in the series, and are contemporaneous with arenaceous deposits in other localities, deposits which Mr. Stigand would presumably place in an upper arenaceous group.

The petroleum prospects of Barbados are dealt with very fully in the official report, in which the difficulties of prospecting with the drill beneath the Coral limestone are considered, and the methods by which wild-cat drilling may be reduced to a minimum are explained.

## Twenty-eighth General Meeting.

A Meeting of the Institution of Petroleum Technologists was held at the House of the Royal Society of Arts, John Street, Adelphi, W.C. 2, on Tuesday evening, 19th February, 1918, Mr. Charles Greenway (President) occupying the Chair.

The Members of Council present were Prof. John Cadman, Mr. E. H. Cunningham Craig, Mr. Arthur W. Eastlake, Dr. F. Mollwo Perkin and Sir Boverton Redwood, Bart. A letter of regret for unavoidable absence was received from Mr. T. C. Palmer.

**The Hon. Secretary** (Mr. Arthur W. Eastlake) announced that the following gentlemen had been elected :—

As Members :—George Frederick Bale, Arthur George Vale Berry (transference from Associate Member), Charles David Geddes and William Alexander Guthrie. As Associate Members : John Arundel Butlin (transference from Student), William Henry Howe, James Nicholls, Junr., and John Wearham.

**The President,** in opening the meeting, announced that, as the papers to be presented were somewhat long, he would, with the consent of the meeting, take them as read. For the benefit, however, of those who might not have seen advance copies, he submitted a synopsis of the chief points dealt with.

## A New British Oil Industry.

By E. H. Cunningham Craig, B.A., F.R.S.E., F.G.S., *Member*,
Dr. F. Mollwo Perkin, F.I.C., F.C.S., *Member*,
A. G. V. Berry, *Associate Member*, and
Dr. A. E. Dunstan, F.I.C., F.C.S., *Member*.

### I.

At the commencement of the war it is probable that there were very few members of this Institution to whom the thought did not occur that a shortage of mineral oils in this country would sooner or later become apparent.

An unscientific Government cannot be expected to see so clearly ahead as a technical expert or body of experts, and it was left for the Council of this Institution to take two important steps, which will be admitted to have been in the right direction.

At the beginning of 1916 two committees were appointed by the Council, one to investigate and report on the desulphurisation of oil from Dorsetshire shale, and one to investigate the supplies of all

materials in this country from which oil can be obtained by distillation. The latter Committee, after several meetings and much discussion, presented a report towards the end of 1916, indicating that a very great quantity of mineral oil could be produced if necessary, and that much material now neglected or treated as waste could be utilised for the purpose.

Government Departments were afterwards formed to undertake detailed research into the whole question, and to produce the oil as speedily as possible. It is well-known that much research and preliminary experimental work has been accomplished, but as another year has passed without seeing the inception of an industry in supplying mineral oils from new indigenous sources, it is felt that the Petroleum Technologists' Institution must take the lead again in showing, not merely what might be done in developing indigenous supplies of oil, but what must be done, and done quickly, to avert the possible oil-famine that looms ever nearer.

There are several sources from which oil can be obtained in this country by distillation.

These are—

(1) Oil-shales.
(2) Coal.
(3) Cannel coals and torbanites.
(4) Blackband ironstones.
(5) Lignite.
(6) Peat.

Of these the only source at present being utilised is oil-shale, and that is being mined and retorted only in Scotland. The Scottish Shale Oil Companies, after many a bitter struggle against adverse circumstances, have attained to a very strong position. Of the many Companies which once existed only a few survive, and it is only by concentration of work, keeping working and managing costs down to a minimum, and recovering every possible by-product, that a financial success has been achieved.

The distillation-process is conducted at a high temperature, so as to produce a maximum of ammonium sulphate and solid paraffin wax, while the oil is really in the nature of a by-product.

The tonnage of shale mined per annum before the war was approximately 3¼ million, yielding about 320,000 tons of oil. From this not more than 60 per cent. of oil fuel can be extracted by refining, while the percentage of petrol is negligible, and the percentage of heavy naphtha small. The war has caused a considerable diminution in output, but every effort is now being made to increase production, with distinct success.

Other shales, such as the Kimmeridge shales of Dorset and Norfolk, are not yet being worked commercially, in spite of strenuous efforts, and there remains much to be done before a regular supply of oil can be counted upon from these sources.

Of the other sources of liquid fuel, coal yields too little, and is too valuable, to be utilised on a large scale, lignites are not yet opened for development on a sufficient scale, and peat has proved troublesome and expensive to treat owing to the difficulty of eliminating water.

This leaves the cannel coals, torbanites and blackband ironstones, which are closely associated, and in many cases easily to be obtained.

Cannel coal differs from ordinary coal by being less highly carbonised: it contains many fragments, strings and particles of vegetable matter still showing their natural forms, though flattened by pressure, and sometimes the internal vegetable structure is also still in evidence. The percentage of hydrogen to carbon is higher in a cannel coal than in an ordinary bituminous coal, the percentage of inorganic matter is usually higher also, and the fracture and general appearance serve to distinguish this variety of carbonaceous deposit. The lustre is sometimes dull, sometimes bright, the fracture is conchoidal or semi-conchoidal, and lamination is as a rule not well-defined. Most cannels contain a very large number of spores, both macro-spores and micro-spores, and these are usually in a condition described as "jetonised," appearing dark-yellow or reddish-brown in thin microscopic sections. Such spores are believed to yield on distillation waxes and resinous compounds, while the other vegetable bodies yield tarry oils and tarry acids.

Torbanites, though very similar in outward appearance, are essentially different from true cannels. There has been a very prevalent idea that the famous "Torbanehill mineral" of Bathgate was a deposit *sui generis*, of great rarity and unknown in other parts of the country. This idea is entirely mistaken; torbanites are known in many of our coalfields, e.g. North Staffordshire, Northumberland, Fife, Lanarkshire and Cumberland, though none so far discovered is so rich as the typical "Torbanehill mineral."

A torbanite consists essentially of a coal matrix in which are imbedded certain oval, spherical or irregular yellow or brown bodies which have been designated conveniently as kerogen. These bodies have been described as algæ by certain French geologists (Renault, Bertrand, Potonié), as macro-spores by Prof. E. C. Jeffrey, and as resin globules by Mr. H. R. J. Conacher. That they are not organic bodies can be very easily demonstrated by

microscopic examination, and that they are not resinous can be proved by chemical analysis. Extensive researches, which it would be out of place to recount in this brief paper, have proved that these kerogen globules contain a considerable proportion of inorganic mineral matter in close, and apparently chemical, combination with hydrocarbons of organic origin. In a torbanite we have, in fact, preserved for us a half-way stage between the carbonaceous and the petroliferous phases, and it is noticeable that where, in a thick coal-measure series, torbanites are frequent in the upper members, seepages of crude petroleum are equally prominent in the lower strata.

Torbanites have a clean conchoidal fracture, as a rule, a fairly high percentage of ash, and a streak that varies from yellow to dark-brown.

The kerogen globules vary greatly in size, shape and numbers in different deposits of this nature, and they have been proved to undergo a curious form of degeneration of which four stages can be distinguished. This degeneration is in effect a species of inspissation, and the quality of the oil yielded by distillation varies according to the stage of this degenerative process.

Cannels and torbanites, though, as has been pointed out, essentially different, are really inextricably mixed up. There are few cannels that do not contain some of the kerogen globules, though they may be few and very small, while torbanites contain uncarbonised vegetable matter, spores, cuticle, etc., just as cannels do. Thus, every gradation between a typical torbanite and a typical cannel can be shown, and most of the English torbanites are known as cannels or gas-coals, or sometimes even as black shales when the lamination is distinct. It is thus convenient to consider torbanites and cannels together, and to class both under the generic title of cannel when dealing with practical questions of oil-production. But one important point must be noted: the kerogen globules yield on distillation oils of the paraffin series and olefines, and the fresher and less degenerated the kerogen the greater the quantity of light oils produced. The most degenerated types yield quantities of heavy paraffin waxes.

Thus it is possible by microscopic examination of a deposit of this nature to make a good rough estimate, not only of the quantity of oil per ton that can be obtained, but also of the quality of the oil.

The occurrence of cannel and torbanite in the field is very interesting. Occasionally there is a good seam of workable thickness, from 3 ft. to as much as 6 ft. thick, but most of the cannel supplies come from composite seams. The roof or the floor of a coal seam

is often cannel, or there may be one or more bands of cannel toward the centre of the seam. Occasionally such central benches are more than 3 ft. thick. Bands in the centre of a seam must be worked with the coal, but bands forming roof or floor are often left in the mine, unless there is a market for cannel, e.g. at neighbouring gas-works. The value of the cannel as fuel is frequently small compared with that of the coal, chiefly owing to its higher ash percentage, which may be as much as 20 or even 30 and seldom falls below 10. So the cannel that is brought to bank at well-conducted collieries is separated on the belts from the coal, and not allowed to be sold with the best fuel. In war-time, as probably everyone has experienced, everything that is black and will burn is apt to be mixed with domestic coal supplies, and much cannel that was previously unsaleable may be found masquerading as "best brights." Still, large quantities of cannel are being brought to bank, and often thrown on the waste heap, and the dumps of many collieries bear clear evidence that for many years cannels have been rejected as useless. A very much greater quantity, however, is never brought to the surface, but is either thrown into the goaf or remains as roof or floor, irrecoverable and lost to the nation. Besides true cannels there are also bastard cannels and impure coaly or canneloid bands that cannot under any pretext be sold as coal, and that consequently accumulate on the waste heaps. Such bands have various local names in different parts of the country, e.g. Jacks, Rattlejacks, Gees, Rattlers, Batts, etc. But though making very inferior fuels, or even being useless as fuel, these deposits, which in many cases have to be worked with the seams, contain kerogen globules and uncarbonised vegetable matter from which oil can be obtained by distillation, and therefore such material has a distinct value, entitling it to be regarded as something more than a waste product of the mine.

It is here also that we must consider blackband ironstones. Many of the famous seams of that material have been worked out, but there still remain a great number of inferior or thin seams which can be utilised. They are essentially ironstone seams in which there is a very intimate association of iron oxide or hydrate with carbonaceous material. Microscopic examination has demonstrated the peculiarly close association between the iron and the carbonaceous contents of a seam, and has proved that the latter is kerogenous, or only slightly carbonised, and is thus capable of yielding oil by distillation. In England, Scotland and Ireland, such seams have been detected, and in many instances the ironstone is associated with cannel seams highly torbanitic in character.

Such seams, if worked at all, are heaped in bings in the open and set fire to, a certain quantity of coal usually being mixed with the material to start combustion. Once well alight the carbonaceous material in the ironstone and associated cannel is sufficient to support combustion, and to effect the complete calcination of the iron content, which then can be sent to the blast furnaces, chiefly as ferric oxide, all the valuable volatile contents of the deposit having been dissipated in air, which, needless to say, is not rendered more pleasant to breathe in the neighbourhood of the burning bings.

The wastefulness of this method of treating ironstones, the cost of handling, and the expense of supplying coal as subsidiary fuel in the bings, have been recognised and denounced many a time, but the innate conservation of our industrial methods allows the practice to continue.

That a better use for the blackband seams can be found does not rest upon theoretical considerations alone: Mr. D. V. Hollingworth has demonstrated recently, on a small but practical scale, that by his patent process the oil contents of a blackband seam can be extracted by distillation of the volatile matter, and the fixed carbon left in the most intimate association with the iron contents. It is claimed that the ironstone thus treated is in a better condition, both chemically and physically, for treatment in a blast furnace, that in fact some four cwt. of coke per ton of ironstone can be saved, and that the extraction of the metal as pig-iron can be effected more quickly and possibly at a slightly lower temperature, thus ensuring less wear and tear in the furnace. Furthermore, in the preliminary retorting to produce the ironstone-cum-fixed-carbon which Mr. Hollingworth designates "carbousiron," the nitrogen contents of the deposit can be collected as ammonium sulphate, and it is possible to retort at such a temperature that sufficient uncondensible gas is produced to supply the heating power to the retorts, and thus make the process practically self-supporting. There is nothing mysterious or unprecedented about this method, but it does away with a very wasteful process, reduces fuel consumption both in bings and blast furnaces, furnishes the latter with a superior raw material, and makes available two valuable by-products—oil and ammonium sulphate.

But perhaps the most significant point to note is this: that many seams of composite nature containing coal, ironstone and torbanitic cannel are known, and are at present unworked because they are too thin as ironstones to be mined profitably, while there is no sale for them as cannel, and the coal is also too thin to work. Any process which will enable such seams to be mined with a profit

—and many such seams are near the surface, and could be cheaply and easily extracted—will increase both the coal and the iron supply of the country, and contribute appreciably to the supply of oil and ammonium sulphate.

On the basis of these various deposits, cannels and bastard cannels, torbanites and blackband ironstones, it is proposed to found a new industry in this country. This industry will be simply the low-temperature carbonisation of the material, with the extraction of oil and all by-products that can be produced in sufficient quantity.

There are several low-temperature carbonisation processes in this country that have been demonstrated experimentally and on a fairly large scale, and all have their respective merits, advantages and disadvantages. Material that intumesces and cokes is unsuitable for some forms of retort, but can be dealt with in others. It is not suggested, therefore, that any one process should be adopted and applied universally; the particular material to be treated in each district must be considered.

The great objection to any low-temperature process is that the maximum production of ammonium sulphate, one of the most valuable products of the Scottish shale industry, cannot be obtained unless retorting is carried out at a fairly high temperature. On the other hand, working at a high temperature loses the bulk of the light oils, which are cracked, with the formation of large quantities of uncondensible gas. But here the scientific classification of the various deposits to be dealt with comes to our aid. A torbanite yields at the best a small percentage of ammonium sulphate, but a large percentage of light oils, especially if the kerogen has not suffered greatly from degeneration. On the other hand, a true cannel may yield but little light oil, but a large percentage of ammonium sulphate. For the former, therefore, a low-temperature carbonisation is indicated, and for the latter as high a temperature as is consistent with an adequate production of oil. In most cases, doubtless, a compromise can be arranged on the basis of the most economical working; sufficient gas to heat the retorts must be produced, and at the temperature necessary to produce that quantity of gas, though the maximum yield neither of light oil nor of ammonium sulphate could be obtained, the production of both might well be sufficient for practical working. Alternatively, it should be possible in many cases to utilise the residue after retorting in a producer to make all the gas necessary for running the plant, and at the same time recover all the ammonium sulphate. The most economical method in each case will be

determined by local conditions, and by the particular characters of the raw material, thus necessitating an efficient control of method by research experts.

The great question that naturally presents itself when any such new industrial development is contemplated is "Will it pay?" On this question there is, of course, room for two opinions, and discussion with practical engineers and chemists has made it clear that practical demonstration is worth more than any theorising on such a subject.

But it is possible to give some idea of what results may be expected, and then to compare such results with those obtained in allied industries.

In the first place, the yield of oil per ton must be considered. There are very few cannels—and these are all torbanitic—that can be counted upon yielding as much as 50 gallons of water-free oil per ton, though many are capable of 40 gallons. Among the worst of the bastard cannels a yield of from 20 to 25 gallons can be expected, and unless oil of unusually good quality be produced, or the amount of available material be very large and easily and cheaply obtained, it would probably be inadvisable to treat material giving a lower yield than 25 gallons per ton. Blackband ironstones may give a much lower yield, but they are in a different category, the iron being the primary product. Over the whole country it is probable that the cannels and torbanitic cannels can be counted upon to give an average yield of from 33 to 35 gallons of crude oil per ton. This oil will naturally vary in quality according to the nature of the raw material and the method of retorting employed. The petrol percentage will probably vary between 4 and 10, and refining for the purpose of producing fuel oil should yield from 60 to 70 per cent. of the crude oil.

The maximum of ammonium sulphate that can be obtained, calculated upon the nitrogen content of the raw material, is large in many cases, running to over 60 lb. per ton, but except where high-temperature carbonisation is employed, or the residues from a low-temperature process utilised in a producer, the maximum cannot be recovered. Low-temperature retorting alone cannot be expected to yield more than 20 to 25 lb. per ton. It is therefore difficult to make any estimate of what an average yield of ammonium sulphate for the country would be, but let it be taken for purposes of comparison at from 30–40 lb. per ton of material retorted.

The yield of solid paraffin wax, another valuable by-product obtained in the Scottish shale-oil industry, cannot at present be

estimated, but it is not likely to be so large as in the case of the Scottish oil-shales.

Comparing these estimates with the results obtained by the Scottish Oil-Shale Companies, some interesting facts come to light. These Companies obtain a yield of oil of approximately 22 gallons, and a yield of ammonium sulphate of 42 lb. per ton. Thus, so far as oil is concerned, cannel distillation has a decided advantage over shale distillation, but the position as regards ammonium sulphate is in favour of the Scottish Companies.

Considering the cost of raw materials the comparison can be carried a stage further.

The oil-shale mined and delivered at the retorts in Scotland costs approximately 5s. 6d. per ton, and such a low price enables the Companies to work very inferior shale, so far as oil-yield is concerned, if the production of ammonium sulphate is high.

The cannels and torbanites cannot be expected to be obtained at such a low average price. There is a large quantity of what is really waste at collieries that could be obtained more cheaply, but when cannel seams have to be specially worked, or larger timbering becomes necessary to allow of the floor or roof of a seam to be extracted and brought to bank, the mining costs must be considered. Again, the miners, if required to load the hutches with cannels and bastard cannels as well as coal, may demand to be paid for it as coal. But with contracts made for the retortable material which can be mined without difficulty, yet which it is in the collieries' interests not to permit to be mixed with the coal, a fair price can no doubt be arrived at. There are few collieries which, before the war, would not have been glad to ensure a price of 7s. per ton for such retortable material as they have to mine with the coal. Cannel seams specially opened and worked, and some of the rich cannels that have always had a good sale to gas-works, must be considered differently.

It is obvious that the success of a cannel distillation industry must depend upon the cordial co-operation of coal owners, and that therefore a fair price must be paid for the raw material. Taking the good with the bad, it is probable that the average price to be paid over a term of years would not be greater than 10s. per ton.

A ton of cannel at 10s., yielding 33 gallons, could compete with a ton of shale at 5s. 6d., yielding 22 gallons, as the output would be 50 per cent. greater with the same overhead charges. But the transport of material to the works, the probable lower yield of ammonium sulphate, and the possibility that low-temperature retorting may be more expensive than a high-temperature process

have to be taken into consideration, all points to the advantage of the shale-oil industry. Against these, the fact that the oil obtained by low-temperature distillation will be of greater value than the Scottish crude shale oil may be placed, and it must also be remembered that the Scottish Shale Companies are very prosperous, and have been paying large dividends for many years.

It must be conceded, however, that the advantage so far is with the Scottish Companies but for one point, and that is perhaps the most important of all.

The Scottish Shale Companies have to deal with an enormous quantity of useless residue after retorting. No use has been found for it; it has to be loaded and transported to huge tips which are constantly increasing in size, while rental of new land for new tips is a recurring expense.

But the residue from the retorting of cannel is not by any means useless. Though it contains a considerable percentage of mineral matter in the case of the poorer grades it can be worked up into very fair briquettes, while the residues from the better grades can be utilised in producers, to give not only all the power-gas that is required, but the full yield of sulphate of ammonia. Thus, instead of being a useless expense the residues may be made a source of profit, and there can be little doubt that it is on the use of the residues that the success or failure of a cannel distillation industry depends.

Indications have not been wanting that the suggested establishment of a low-temperature cannel distilling industry has not been well received in certain quarters, and in discussion much destructive criticism has been directed against such ideas as have been put forward tentatively as to the scope and desirability of the work. These criticisms have chiefly taken the form of queries as to the possibility of such an industry paying its own way. No objection, however, is raised to the taking of temporary war-time measures to produce a little more oil in this country, in scattered localities, by the utilisation of such gas-works as may be able to apportion such retorts as could be made suitable by small alterations for the production of oil. Such temporary enterprises would no doubt cease as soon as the immediate necessity for them had terminated. It is quite evident, however, that an industry cannot be started successfully by such piece-meal work, and it would no doubt be possible to show on the results of working that the production of oil from cannels had not been on a really paying basis.

The industry, if started at all, must be started on broad lines, and on a large scale. It is here that the experience of the Scottish

Shale Companies comes to our aid. Of the fifty-odd Companies that once existed, only five have survived, and it was only those with sufficient financial resources that were able to buy up the businesses and fields of those that failed, that brought them under one management, worked on a large scale, and instituted every economy in handling, retorting and refining that finally attained to a secure financial position.

So in cannel distillation, only large central works must be projected, and they must be placed with due regard to supplies of retortable material and facilities for transport. The through-put of cannel should be at least 1,000–2,000 tons per day, and in some instances it might be more.

Each works must have its refinery for the treatment of the crude oil, and power to run works and refinery can be obtained by utilising the residues, or a portion of them, in producers. Any residues left over can be briquetted, using the heavy residues from the refinery as binding material.

At least six such retorting and refining works could be established without any difficulty; the localities in which they should be placed are determined naturally, as are the districts from which their supplies would be drawn, and the actual sites will not be difficult to select.

Several other districts could support somewhat smaller installations, which might be increased as new sources of raw material are opened by mining.

There are, it is true, difficulties to be faced, and not the least is that it is necessary to maintain coal supplies as nearly as possible at their present level.

The mining of cannel as distinct from coal must of necessity reduce the local supply of coal, but there are compensations that must not be lost sight of. In many localities a seam half cannel and half coal, and not sufficiently thick to be mined at a profit for either, is at present neglected; were it mined, the coal supply would be increased.

There is the difficulty of labour and of trades-union regulations which make it at present impossible to employ German prisoners or other aliens where the labour supply is short.

But difficulties are made to be overcome, and this applies both to natural and inevitable difficulties, and to those which are manufactured either intentionally or inadvertently.

The coal shortage, about which the newspapers had so much to say, was, it is to be feared, greatly exaggerated. It was the distribution and the transportation that were to blame rather than

the supply, and miners were working only two or three days a week in more than one district while London was crying for coal.

These difficulties make excellent excuses for inaction, but not reasons that can carry any weight with those who have seriously studied the subject.

Viewing the question in the broadest way there must be sacrifice of some interests—though not necessarily serious sacrifice—if the end is to be achieved.

Nor have the oil-importing and oil-producing interests much to fear from competition. The total quantity of oil that can, under even the most favourable auspices, be produced in this country can never make it independent of supplies from overseas. The price of ammonium sulphate may be reduced by a greatly increased production, but that salt is urgently needed for extended agricultural developments. The price of oil will probably never fall again to its pre-war level. There is therefore room for all to prosper without ruinous competition.

The goal to be aimed at is merely some 400,000 tons oil fuel per annum and some 6 or 7 million gallons of petrol, besides intermediate oils. These figures may seem small, but they may help very patently to tide over difficulties and shortages that the hazard of war may bring at any time.

Furthermore, the new industry that is suggested will add directly to the wealth of the nation by utilising waste products of our mines, and deposits long neglected that are being lost for ever. The amount of such material is enormous, and it can be made available rapidly in proportion to the determination with which the establishment of this new industry is prosecuted.

E. H. C. C.

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## II.

Although there have, from time to time, been discussions in the Press and Technical Journals as to the relative merits of high- and low-temperature carbonisation, there is in the minds of many only a confused idea as to the difference between the two processes. This is partly due to exaggerated claims and to partisan feelings. In gas-works and in coke-oven practice, high temperatures are employed for carbonisation, because, in the one case large volumes of gas of high calorific value are required, and in the other a hard coke for metallurgical purposes. In gas-works tar and sulphate of ammonia are by-products, and it is not unusual to hear a gas-

engineer say, "I don't care anything for the tar, it is the gas I want." This attitude is, of course, quite natural. With low-temperature carbonisation the yield of gas is comparatively small, but the maximum yield of oil is obtained, which when refined yields fuel-oil, motor-spirit, etc. Generally speaking, however, sufficient gas is produced to heat the retort settings, and carry out the carbonisation, and there may be a small surplus, which can be used for power.

The products contained in high-temperature gas-tar are entirely different from those found in the oil produced by low-temperature carbonisation. Benzol, toluol, carbolic acid and other products required for the manufacture of high explosives are obtained from high-temperature tar, and it is not too much to say that in this war the gas-works of the country have saved us from defeat by the Germans. Furthermore, ships are required for other purposes, to carry food, transport troops, and bring machinery and the thousands of articles necessary to carry on the war, and maintain the country.

I have already mentioned that creosote oil from the gas-works can be employed as a fuel-oil, but the amount which the gas-works can supply is strictly limited. The Government has asked the gas companies to increase their production of tar. This can indeed be done, but how? By lowering the temperature of retorting, or, in the case of vertical retorts, passing up steam through the coal as it is being carbonised. With what result, however? In the first case the amount of gas is decreased, and the throughput of coal is also less, that is to say less coal handled daily. Some experiments which were recently carried out in Lancashire in vertical retorts of the Glover-West system, for the Nitrogen Products & Carbide Co., and which I supervised, are of interest in this connection. For example, a special coal was retorted at a temperature of 1,411° C., the throughput of coal in each retort being 4·2 tons in 24 hours. The temperature was then reduced to 1,194°, when the amount of coal passing through the retort was reduced to 2·6 tons in 24 hours—that is, almost halved. Although the amount of tar produced per ton of coal carbonised was increased, the net amount produced in 24 hours was much less, and of course the same applied to the net yield of gas, which was insufficient for the town requirements.

In the case of steaming, considerably larger yields of tar and gas are obtained. The tar, however, contains very little benzol and toluol, and what there is is difficult to purify because of the admixture of aliphatic hydrocarbons. Now, in low-temperature carbonisation, as already mentioned, large quantities of oil are produced, but this oil contains no benzol or toluol; it is, therefore,

useless for explosives, aniline dyes, etc. On the other hand, the lower fractions yield a light spirit which can be employed for aeroplanes and motor-cars. The higher fractions produce fuel-oil, the yield in some cases being very considerable.

A few examples of the products obtained from different coals, carbonised at low temperatures, may be of interest.

YORKSHIRE COAL (washed smalls).

17·5 gallons of crude oil per ton of coal carbonised was obtained.
Yield of sulphate of ammonia—22 lb.
The oil yielded, on fractionation:

| | |
|---|---|
| Oil distilling up to 150° C. ... ... | 3·0 gallons. |
| Fuel-oil ... ... ... ... ... | 11·0 „ |
| Paraffin wax ... ... ... ... | 8 lb. |

YORKSHIRE CANNEL.

Yield of crude oil—70 gallons per ton of coal carbonised.
Yield of sulphate of ammonia—3·2 lb.
The oil yielded, on fractionation:

| | |
|---|---|
| Oil distilling to 170° C. ... ... | 7·4 gallons. |
| Fuel-oil ... ... ... ... ... | 49·3 „ |

The first fraction was taken up to 170°, instead of 150°, for a special purpose. There was only a small portion of paraffin wax, which was not estimated.

SLACK FROM BITUMINOUS YORKSHIRE COAL.

Yield of crude oil—24 gallons per ton of coal carbonised.
Yield of sulphate of ammonia—22 lb.
The oil on fractionation yielded:

| | |
|---|---|
| Oil distilling to 170° C.... ... ... | 2·8 gallons. |
| Fuel-oil ... ... ... ... ... | 12·0 „ |
| Paraffin wax ... ... ... ... | not determined. |

A SCOTCH CANNEL.

Yield of crude oil—37 gallons per ton of coal.
On fractionation the following yields were obtained:

| | |
|---|---|
| Oil to 150° C. ... ... ... ... | 1 gallon. |
| Fuel-oil ... ... ... ... ... | 22 „ |

A COAL FROM SPAIN.

Yield of crude oil—22·5 gallons per ton of coal carbonised.
Yield of sulphate of ammonia—18·5 lb.
The oil yielded, on fractionation:

| | |
|---|---|
| Oil up to 160° C. ... ... ... | 2·0 gallons. |
| Fuel-oil ... ... ... ... ... | 13·5 „ |

Many more examples might be given, where the yields vary from 20 to 40 gallons of crude oil. I have, however, picked out these examples to illustrate the varying yields of oil produced from different coals. From selected cannels 40 gallons per ton may generally be expected. It must be borne in mind that after distilling off the bulk of the volatile matter from the coal, over 70% of the coal still remains in the form of valuable smokeless fuel. When the coal is burnt in an open grate with all its volatile matter in it, that is to say before it has been retorted, the volatile matter goes off in the form of smoke and flame, and is thus largely lost. Surely it is better for the country in every way to obtain the oil, and still have the fuel. Just think of the improvement in the atmosphere of our large towns and cities if smokeless fuel only were employed! Those who wished could still have their usual fires, because this fuel burns excellently in open grates, and throws out a strong heat.

The Staffordshire blackband iron-ore contains large quantities of volatile matter, and for this reason it has not been found feasible to smelt it, without first calcining it in the wasteful manner described by Mr. Cunningham Craig. It has now been found that the volatile matter in the ore can be obtained in the form of oil by low-temperature distillation. This leaves the ore in a form in which it can be smelted to obtain iron. So here is another important use for low-temperature carbonisation, because in any case before smelting the ore the volatile matter has to be driven off, and why waste the valuable oil?

The actual temperatures employed for low-temperature carbonisation vary from 450° C. to 550° C., but different coals require different treatment; some will give up their volatile matter at a lower, and others at a higher temperature. The wear and tear of the plant is when low, less than when very high, temperatures are employed.

It has for years been known that oil can be produced, and that in large quantities, from bituminous materials, and that, particularly from cannel coal, the yields are frequently very high, as the second and fourth examples show.

The production of oil in Great Britain to prosecute the war is just as much a necessity as the production of high explosives. Has the question of labour or material been considered in the production of shells? On the other hand, I understand that in reference to oil even private enterprise has been handicapped. The Treasury have not allowed the raising of private money for the purpose of exploiting British propositions for the production of oil from our mineral resources. And it seems to me that, so far as

the country is concerned, we are no further forward than we were at the commencement of the war.

I see it is now suggested that cannel coal can be satisfactorily treated in the shale-oil retorts. Personally, I should doubt this, unless the retorts were considerably modified. On the other hand, the shale retorts are being worked to their full capacity, and therefore new retorts would require to be built.

If we are to build new shale retorts, why not retorts for low-temperature carbonisation, in districts in which rich cannel exists. The shale-oil process is intermediate between high and low temperature, and does not give as large a yield of oil as low-temperature plants, owing to the fact that the retorts are worked for ammonia recovery; in fact, the recovery of ammonia was the salvation of the shale-oil industry.

From considerable experience I would put the average quantity of fuel-oil obtainable by the carbonisation of one ton of cannel at 20 gallons. That is to say, if 15,000 tons of cannel *per diem* were carbonised, some 300,000 gallons of oil would be produced, or 105,000,000 gallons, working the plant for 350 days in the year, and there is also to be taken into account the amount of light oil and paraffin wax produced. Of course this would not be sufficient to supply our needs, but it would be a great help, and would liberate a considerable shipping tonnage which could be used for other purposes.

The amount of creosote oil produced from 1 ton of tar varies considerably, but if we take it that on the average 40 gallons is produced, and that 12 gallons of tar is obtained by the carbonisation of coal in the gas-retorts of the United Kingdom, it will require about 16 tons of coal to produce 1 ton of tar, that is to say, to produce 40 gallons of creosote oil. On the other hand, by carbonising 16 tons of cannel, which as stated above may be expected to yield 20 gallons of fuel-oil per ton, 320 gallons of fuel-oil will be obtained. Furthermore, except to a limited extent, cannel coal is not suitable for gas-works practice or for domestic use.

The Government are urging restricted use of gas. But if less gas is consumed, it is obvious that less coal will be carbonised, and less tar produced.

In any case the present production of oil in the United Kingdom is not a question of cost but of carrying on the war. During this war we have very often been too late.

F. M. P.

III.

*Method of Sampling the deposit of Cannel Coal.*—An accurate evaluation of the cannel coal is one of the most important preliminaries of any enterprise in the distillation of this material for commercial products, and this is dependent on sampling in such a manner that the whole deposit to be worked is truly represented by the sample obtained.

Undoubtedly the best method of sampling is that of taking a vertical core of equal section right through the deposit or stratum at intervals throughout the length, the whole of the cores being broken to a suitable size and then "quartered" until the sample is reduced to a less unwieldy bulk. This is crushed to a smaller size, and again reduced to a smaller quantity by "quartering," the final sample being obtained from this by a third quartering operation after the material has been reduced to a fine powder. The crushing of large amounts of material is essentially a laborious task, unless one or other of the mechanical breakers on the market is employed.

*Testing of the Cannel for yield of Oil.*—The tests usually required in the first instance are those necessary to indicate the nature and yield of the various products obtainable by destructive distillation of the material under working conditions. The volatile contents, "fixed carbon" and ash, are estimated on the cannel coal by igniting a known weight in a crucible, and moisture by drying in a constant-temperature oven under such conditions of time and temperature that the water is expelled without undue oxidation of the sample.

Cannels as won contain moisture ranging from 1 % to 11 %, and averaging approximately 5 %. The volatile organic matter varies from 18 % to 45 % of the material.

The yield of oil per ton of dry cannel coal at moderate temperatures may be taken as equal to a gallon for every one per cent. of volatile matter, but for the lower amounts of volatile contents the yield is somewhat lower than this, whilst for higher percentages of volatile matter, this basis of calculation gives a yield of oil lower than is actually obtainable. Fig. 7 approximately illustrates the form of curve obtained by plotting percentages of volatile matter against the yields of oil.

Naturally the yield of oil is very largely dependent on the temperature-conditions of retorting, high temperatures being productive of less oil, but more favourable to the formation of ammonia, and the economic question of relative values of these products must largely control the temperature-factor.

The determination of the most suitable temperature for economical retorting is again a question for the chemist to deal with, and no better preliminary work to this end can be recommended than a series of distillations by means of electrically-heated tube retorts under chemical control, in order to ascertain the critical temperature for the production of oil without an undue production of waste gases, waste in the sense that production of gas means loss of oil.

*The Products obtained by Retorting.*—The cannel coal, under the conditions of retorting, loses its organic volatile matter and moisture, and these products are led to the condenser, where the liquid and solid products condense, and the gaseous portion passes to the

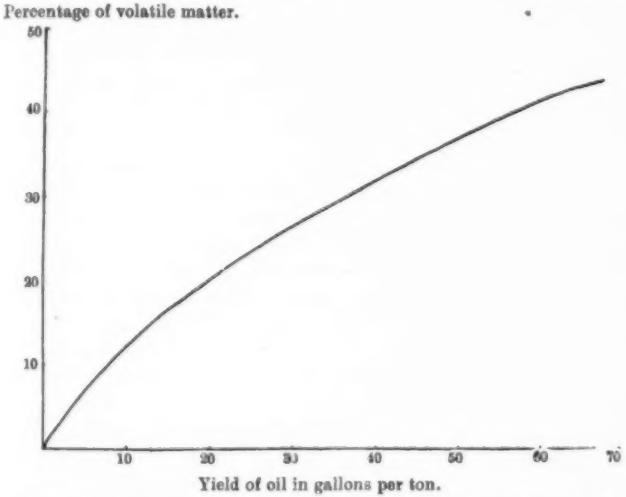



FIG. 7.—Relation of volatile percentage to yield of crude cannel oil.

scrubber. The residue left in the retort is coke. The condensed distillate is a mixture of water with liquid and solid hydrocarbons. The gases, which pass through the scrubber, are stripped of any light oils which have escaped condensation, and are utilised as fuel under the retorts, after the ammonia present is washed out and obtained as ammoniacal liquor. Some ammonia is held by the aqueous distillate condensed.

We have, then, as products of destructive distillation of cannel coal:

(*a*) Water, containing some dissolved ammonia.
(*b*) Oil containing paraffin wax.

(*c*) Light oils from the scrubber, recovered by distillation of the scrubber oil. (Valuable source of motor-spirit.)

(*d*) Ammoniacal liquor (utilised for the manufacture of sulphate of ammonia).

(*e*) Coke.

(*f*) Waste gases, having an economic value as fuel.

The working up of the products takes the following course:—

(*a*) is separated from (*b*) and added to (*d*). This liquid is dealt with on the lines of gas-works practice for the production of ammonium sulphate, a valuable fertiliser.

(*b*) The oil is allowed to settle at a temperature slightly above the setting-point, until the water held in suspension has separated.

(*c*) is added to light distillate from oil (*b*), and the whole worked up for petrol.

## Summary of Previous Views on the Chemical Nature of Cannel Oil.

Although it has been asserted that aromatic hydrocarbons are in the main absent from cannel oil, yet Heusler (*Ber.*, 1892, 1665; 1895, 448) proved that the fraction 80°–93° C. contained 34 % benzene, and the fraction 100°–110° contained 45 % toluene; further, he traced cymene, naphthalene, thiophene, and *cyclo*-paraffins. It thus appears that at a suitable retorting temperature aromatic compounds can be formed, and we should expect to find this from our knowledge of the pyrogenesis of hydrocarbons.

Prof. Dittmar in 1875 obtained undoubted paraffins, at a low retorting temperature, from what was presumably cannel coal (Lunge, "Coal Tar and Ammonia," 1916, i, 41).

From the point of view of gas-making and not of tar production, much work has in the past been done on cannel. The yields of illuminating gas were doubtless brought about by a cracking of the oils produced in the earlier part of the retorting period. For example, when low heats were used, as much as 8 % of naphtha (benzene and homologues) was obtained from the tar. With increased temperatures only 3 % was obtained. Generally speaking, the tar from cannel contained little naphthalene and anthracene, but considerable amounts of paraffins, rendering it objectionable to the distiller, as the aromatic bodies were contaminated therewith.

## Nature of the Products from Cannel Oil.

Whilst obviously the nature of the products depends largely on the temperature of distillation of the cannel, there are well-marked differences between the chemical structure of low- and high-tempera-

ture tars. In the latter case most of the phenolic oxygen is present as simple phenol and the cresols :—$C_6H_5OH$ and $C_7H_7OH$ (*o.m.p.*).

But in the former case, methyl ethers occur largely as well as xylenols. Some experiments on the germicidal activity of low-temperature tar-acids proved very satisfactory.

It should be noted that wood tar, which represents both a low-temperature product, and one widely dissimilar from gas-tar, also yields methyl phenyl ethers, notably guaiacol and its homologues.

The relatively low calorific value of oxygen-containing compounds, and their intrinsic value as disinfectants and germicides, renders it advisable to remove these phenolic bodies by means of an alkaline wash. Thio-derivatives of phenols appear to be present, imparting a characteristic odour to the fraction soluble in alkali. Complex poly-hydroxylic derivatives are also to be found here, causing a rapid darkening on exposure to air.

The lower and more volatile hydrocarbons appear to be mainly paraffinoid, from their specific gravity and other properties. Mixed therewith are olefines and naphthenes and small amounts of diolefines. The refining should not be sufficiently vigorous to remove all the unsaturated hydrocarbons, a fact which is well known to hold good for other motor-spirits of origin other than from petroleum. The acid tar, on being diluted, produces fragrant polymerized hydrocarbons, possibly of value.

As the molecular weight rises, the proportion of paraffin hydrocarbons diminishes, although in all probability the paraffin homologous series is represented by most of its members within the boiling-point limits, and the middle and heavy oil fractions probably consist of saturated and unsaturated ring systems. The very smoky flame, characteristic of these higher fractions, indicates clearly the relative deficiency in hydrogen. Hence they are not so suitable for gas-oil as is petroleum, since they tend on gasification to produce much tar. Whether it will be possible in the near future to apply the well-known hydrogenation reaction of Sabatier and Senderens, opens an interesting line of investigation, although desulphurisation must apparently precede reduction.

The amount of benzenoid hydrocarbons present in cannel oil is largely a function of the retorting temperature. Generally speaking, the aromatic series is not predominant, especially in the lighter fractions, but, towards the end of the distillation, yellow complex polynuclear derivatives appear, which probably consist of picene and chrysene. The nitrogen present in the original cannel coal appears chiefly, after the retorting, (*a*) in the gas, as such, and as ammonia, (*b*) in the liquor, (*c*) in the tar, as bases, and (*d*) combined

in the coke. Unfortunately, as with coal, the bulk of the nitrogen remains in the coke.

The increasing of the yield of ammonia is of the first importance, and will probably be effected by high temperature in conjunction with steam. It is interesting to note that pyridine, the picolines (and probably higher homologues) and quinoline are present in the tar. These bodies are readily removed by an acid wash, and have a commercial value as fungicides.

The sulphur-content of the oils is relatively low, and probably consists of traces of carbon disulphide and thiophene, together with sulphuretted hydrogen (in solution and in the gas) and heterocyclic thio-derivatives.

### Effects of Temperature on the Nature of Cannel Oil.

It is well known that at a low carbonisation temperature there is produced a tar not so rich in aromatic compounds, particularly of the poly-cyclic series, as is obtained in current gas-works practice. Paraffins, olefines, *cyclo*-paraffins, methylated phenols and fatty bases make their appearance in a low-temperature tar, whilst anthracene, phenol, carbazole and pyridine are largely absent.

Furthermore, vacuum effects, causing rapid clearance of vapours from the heated zone, play a similar part in the avoidance of the formation of condensed ring systems.

### Refining of the Crude Oil.

Owing to the relatively high setting-point, cannel oil must, if a Navy fuel is needed, be refined by distillation to cut out solid paraffin. Furthermore, there will be at the same time a removal of the lighter fractions to yield motor fuel.

Under such a scheme there would be obtained:—

A. Benzine. Approximately 3 %, sp. gr. about 0·740–0·750, with a final boiling-point of 170°.

B. Intermediate Oil. Approximately 12 %, sp. gr. about 0·800, flash-point about 80° F. Such an oil would be an excellent light fuel for tractors, etc.

C. Navy Fuel Oil. Approximately 50–60 %, sp. gr. about 0·870, flash-point over 170° F., and setting-point below 25° F.

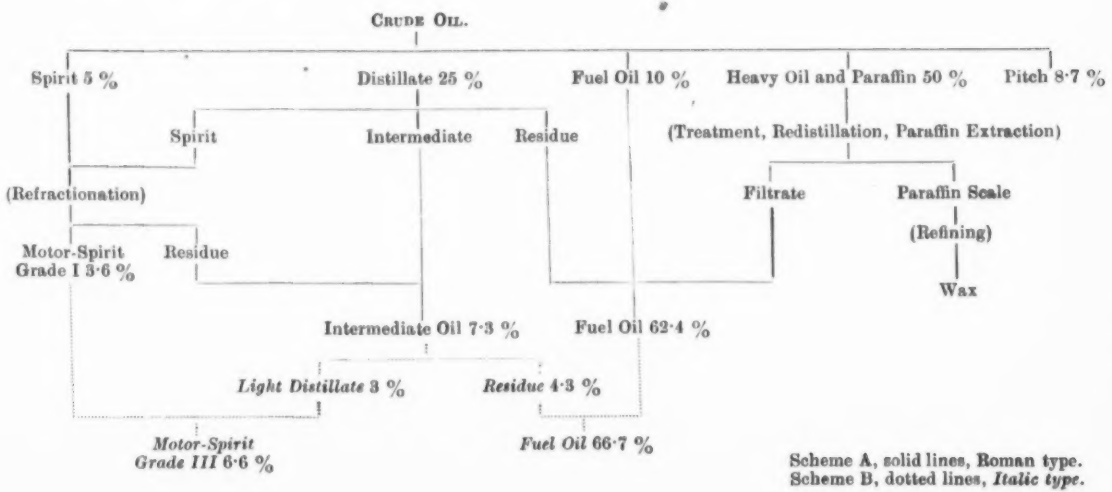
D. Paraffin Scale. Variable, averaging approximately 3–4 %.

E. Pitch.

The final product may be hard or soft, depending on the demand. It is much more free from carbon than coal-tar pitch, approaching a bitumen. At the worst, mixed with oil, it would produce a works fuel.

Furthermore there is a possibility of distilling the pitch in coking

## Scheme for Refining of Crude Cannel Oils.




Scheme A, solid lines, Roman type.
Scheme B, dotted lines, *Italic type*.

stills, and recovering therefrom more heavy oil, rich in the solid hydrocarbons, and coke eminently suitable for use in processes requiring a high-grade solid fuel.

It will be seen that nothing in the above scheme is new or original. Well-known routine practice is followed.

A specific illustration may be of interest (diagram, p. 131).

| | A. | B. |
|---|---|---|
| Motor-Spirit 1st Grade ... ... ... | 3·6 | — |
| „ „ 3rd „ ... ... ... | — | 6·6 |
| Intermediate Oils ... ... ... ... | 7·3 | — |
| Fuel-Oil ... ... ... ... ... | 62·4 | 66·7 |
| Scale ... ... ... ... ... ... | 5·0 | 5·0 |
| Pitch ... ... ... ... ... ... | 8·7 | 8·7 |
| Loss in refining ... ... ... ... | 13·0 | 13·0 |
| | 100·0 | 100·0 |

Note.—The motor-spirit absorbed in the scrubbers during the distillation of the cannel coal has not been included in the scheme outlined above. This product was separated by fractionation of the oil used for scrubbing, and the yield was 3 % of the yield of crude cannel oil.

Various Tests on Cannel Oil.

Boghead Cannel Oil:—

Sp. gr. ... ... ... 0·916
Water ... ... ... 0·5 %
Distilling up to 170° C. = 8 %
„ 170° to 230° C. = 10 %
„ 230° to 270° C. = 13 % Sp. gr. ... 0·832
„ 270° to 350° C. = 38 % „ „ ... 0·886
Pitch ... ... = 30·5 %

Tar acids averaged 9 % of the total distillate.

Another oil:—

Sp. gr. ... ... ... 0·940
Water ... ... ... 7·0 %
Distilling up to 170° C. = 6·5 %
„ 170° to 230° C. = 8·0 %
„ 230° to 270° C. = 9·5 %
„ 270° to 330° C. = 27·0 %
58·0 %

Tar acids averaged 7 % of the total distillate.

The above assays of course do not include the light oils recovered from the gas.

Another cannel yielded 37 gallons of oil per ton, which was split up into:—

8 % of motor-spirit.
9 % of intermediate oil.
51 % of heavy fuel-oil.

GENERAL DATA ON CRUDE CANNEL OIL.

| | | |
|---|---|---|
| (*a*) | Specific gravity ... ... ... | 0·887 to 1·000 |
| (*b*) | Sulphur ... ... ... ... | 0·4 % to 1·1 % |
| (*c*) | Setting-point ... ... ... | 5° C. to 30° C. |
| (*d*) | Water after partial separation ... | 1 % to 4 % |
| (*e*) | Calorific value of dry oil ... | 9·550 to 9·655 calories per gram = 17·190 to 17·379 B. Th.U per lb. |

It is quite obvious that the higher setting-points, due to the presence of solid paraffins, may be overcome by the removal of these bodies. Such removal may be carried out in two ways:—

(A) By routine refining practice, actually recovering the paraffins.

(B) By destroying the paraffins by the effects of high-temperatures.

For example, a fuel-oil was prepared by "topping" a mixed average cannel oil made by blending five different samples. This oil possessed a flash-point of 178° F., and a setting-point of 50° F. On the crude oil being passed through a tube heated to 500°–530° C., the solid paraffins were decomposed, and a 70 % yield of cracked oil was obtained. On distillation this produced:—

| | | |
|---|---|---|
| 9·0 % motor-spirit | = 6·3 % | on crude cannel oil. |
| 13·6 % intermediate oil | = 9·5 % | „ „ |
| 69·0 % fuel-oil | = 48·3 % | „ „ |
| 8·4 % pitch and loss | = 5·9 % | „ „ |
| gas and cracking loss | = 30 % | „ „ |

The fuel-oil thus obtained was fluid at –4° C., and appeared to contain no solid paraffins whatever.

The motor-spirit suffered from the usual disadvantages of cracked spirit, being yellow in colour, characteristic in odour, and needing stringent refining.

The intermediate oil is suggested as a solvent for the pitch, producing works fuel.

It might possibly be urged that the scheme (B) outlined above is in no sense so good as the alternative method (A), but it must be

borne in mind that no refrigerating plant for the extraction of wax is necessary.

The disposal of by-products in such an industry as the making of fuel-oil and petrol from cannel oil should not be a very difficult matter. The Tarless Fuel Syndicate has already shown that they can find a market for the coke, and a cannel of high ash content can always be distilled with a coal or semi-coal of low ash.

A. G. V. B.: A. E. D.

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## *DISCUSSION.*

**The President** said that the subject dealt with by the foregoing papers was, as members would be aware, one of the very greatest importance at the present time, because of the enormous national need for the development, to the utmost possible extent, of the oil resources of this country. He felt sure that the Government Department which was dealing with the matter would welcome any light that could be thrown on the question by the members of the Institution, in view of their special knowledge of the subject.

The papers dealt with the practicability of using cannels and kindred substances as a source of oil supply, chiefly from the scientific or technological side, but, to complete the case, more information was required on the practical and economical side. There was, he thought, no doubt, from the evidence available, that, given a sufficient supply of cannels in any one district to ensure economical retorting and refining, and provided that mining costs were not in excess of those now obtaining in Scotland for shale, the suggested source of oil supply was one that should not be neglected, inasmuch as the quantity of oil obtainable was at least as great as that obtainable from shale, whilst the residues would be more valuable. For himself, he would like more definite evidence (which members might be able to give) as to the quantity of cannel readily available in particular collieries or districts, and as to the price at which it would pay collieries to sell them if it raised.

Another point on the practical side, regarding which information was necessary in the present time of great shortage of metal and man-power, were those relating to the quantity of steel and the number of men required to obtain the quantity of crude oil needed to produce the fuel oil which Mr. Cunningham Craig had indicated as the goal to be aimed at. To carry that quantity of oil and the corresponding production of petrol from the present sources of supply would give constant employment to a number of tank

vessels. If those vessels could be released for other employment, it would be equivalent to the building of so many new vessels, for which a quantity of steel would be required. Could it be shown that this, or a smaller quantity of metal, converted into retorts, stills and briquetting plant, would suffice to deal with Mr. Craig's unit? If so, it would go a long way to support the case for the utilisation of cannel coals. The number of men required for the construction of the vessels and of the distillation-plant would probably be, ton for ton, approximately the same, and therefore, from the point of view of man-power, the only questions to be considered were (1) how many men would be required to raise the quantity of cannel necessary to produce Mr. Craig's unit of oil fuel, and (2) how many men would be necessary to raise the same quantity of coal, less the heating equivalent of the briquettes produced from the cannels? Those were the practical questions which suggested themselves to the speaker from the commercial standpoint. He would be glad if, in the course of the discussion, some speakers could give information on those points.

Before the discussion was thrown open, he wished to point out that it was undesirable that anything should be said which would be in the nature of criticism of the policy of the Department which had been appointed by the Government to deal with the development of the oil resources of the country. The only object of the papers, and of the Council in accepting those papers, had been to give the Petroleum Executive the benefit of the technical knowledge and experience which the members of the Institution collectively possessed, probably to a greater extent than any other body in the country, with a view to assisting in the elucidation of the problems now under the consideration of that Department. As he had said, the development of the oil resources of this country was a national question of the very first importance, and he was confident that the members of the Institution had only one desire, namely, to deal with the question in a national spirit, and to aid the Government in every possible way in the solution of that great question.

**Mr. D. V. Hollingworth** felt that his first duty, in rising to speak in such an historic building, was to thank the Institution for permitting him to be present. Although, no doubt, that building had witnessed the inception of many new industries, he was entirely with Mr. Cunningham Craig in thinking that it had witnessed nothing of such great importance to the Country as the schemes unfolded in the papers under consideration. Indeed,

he should like to thank the authors for having directed the attention of the Country, in so striking a fashion, to the culpable neglect of such valuable sources of fuel oil as the cannels of Great Britain. To one who, like himself, had worked for many years amidst these raw materials, it was particularly gratifying to find so influential a body of gentlemen meeting for the purpose of discussing the subject. He trusted that, as the outcome of the meeting, the Country might in the near future be possessed of larger quantities of fuel oil, spirit, ammonia and coke, so sorely needed.

His main object in rising was to corroborate to the fullest degree Mr. Cunningham Craig's reference to the Blackband ironstones, and, with the permission of the meeting, he would outline the present method of dealing with those ironstones. The custom was to raise and calcine them in the open air. The ores consisted principally of oxides, carbonates and sulphides of iron, mixed with impurities, in which condition they were totally unfit to be put into the blast furnace. The object of calcination was first to reduce, as far as possible, the bulk of the ore by the elimination of impurities, such as carbonic acid, sulphur, etc. By that means the bulk was reduced by about one-third, and the cost of handling the material and of carriage was thus considerably reduced. The disadvantages of the process were the following. The Blackband ores contained exactly similar substances to those present in a good class of coal, and the act of calcining entirely destroyed all those valuable substances. The ores being calcined in the open air, the hydrocarbons, the fuel oil, ammonia and carbon were dissipated into the open air, and lost. Another disadvantage was that the process could not be controlled at all, and considerable losses of the best classes of iron ore were experienced through lack of control. A third disadvantage was the infliction of a serious nuisance upon the neighbourhood by the liberation of vast quantities of hydrocarbons and smoke. The speaker craved permission to refer to the "carbousiron" process, which had for its object the conservation of the valuable substances lost in open-air calcining, and, at the same time, the production of a much better raw material for the manufacture of iron than was at present made from Blackband ores. In all existing processes of preparing this "mine," the ores were heated in the open air, and the whole of the valuable products, excepting the iron, were lost. By the "carbousiron" process certain very important advantages were obtained. The ironstones were heated in a closed vessel, such as a gas retort or a coke oven, and that treatment preserved all the benzene, paraffin, fuel oil, ammonia and coke, left mixed with the iron. The reason

for claiming that the residue left was a better substance for the manufacture of iron than the open bing "mine" was that, as was well known, the Blackband ironstones contained very large quantities of carbon in the form of carbonaceous substances. When those substances were burnt in the open air, the whole of the carbon was lost. By heating the material in a closed vessel, however, the carbon was left behind with the iron oxide in a finely divided condition. It was a matter of very great surprise to all who had seen both the process and the products to find what striking properties were possessed by the "carbousiron." The carbon in the residue was in practically a molecular condition, and since the chemical action (of which the processes in the blast furnace might be taken as an example) depended upon the closeness of contact of the re-acting substances, it followed that the fusion of the iron in the furnace was brought about with very much less consumption of carbon and at a lower temperature. His object in mentioning these particulars was not only to point out that by that system the Blackband ores were a possible source of large quantities of fuel oil, but to insist on the fact that they served also to produce a much better material for the manufacture of iron than was at present being used.

There was another important feature to which he wished to direct attention. In North Staffordshire there were many millions of tons of poor ironstones, left in the ground because they were unremunerative to work; that is, not rich enough in iron to be raised, nor rich enough in oil to work for oil alone. The "residues" were so hopelessly mixed together that it was impossible to separate them, with the result that the ores were left entirely unworked. He knew that in the case of one colliery something like 4½ million tons of these lean ironstones were lying untouched. Moreover, as in that neighbourhood there were six collieries with an equal quantity available, it was easy to calculate the amount of raw material; indeed, in that particular district, so far as oil-bearing ironstone was concerned, the amount was practically unlimited. It was quite clear, however, that unless some means could be devised which could make use of both the iron and the oil which those ores contained there could be no prospect of success. He submitted that the "carbousiron" process would make possible the raising of those lean ironstones. This was the process for which they were waiting. Not only did the process permit the recovery of iron in a better form than present methods allowed, but it made available the oils, ammonia and carbon which the ores also contained. To speak in quantities, he had worked

out a few figures which might prove interesting. These figures were not the result of mere laboratory experiments. The speaker had been a gas-works chemist for fifteen years, had been a coke-oven manager for five years, and had tested almost every coal within fifty miles of Manchester, cannel coals included. As a result of his experience he could bear out what Mr. Cunningham Craig and the other writers of the papers had said. In submitting these figures, based upon practical tests on an adequate scale, he wished to say that in one single colliery in a district in Staffordshire, where 2,000 tons of oil-bearing ironstone were raised every week, and their valuable ingredients wasted, treatment by the "carbousiron" process—distillation in a closed vessel—would yield to the country no less than 500 tons of sulphate of ammonia, 200,000 gallons of motor-spirit, 300,000 gallons of fuel oil, and would save some 28,000 tons per annum of coal and coke.

The speaker further desired to draw attention to another unscientific procedure in blast-furnace practice. He had pointed out that the valuable substances under discussion consisted of iron oxides mixed with carbon. In fact, the carbonaceous ironstones contained over 20 per cent. of carbon, which, by the present system, was sent into the air, but which the "carbousiron" system recovered. The object in the blast furnaces was to reduce the oxides of iron from the higher oxides into metallic iron. The oxides, as they were formed in calcination, were deliberately converted, by burning in the open air, into the higher oxides, only to be again reduced in the blast furnace. By the "carbousiron" process the oxide was not permitted to reach that highest state of oxidation, but remained in the ferrous condition, and consequently did not require anything like so much carbon as would be otherwise used. As a result of wasting carbon by open-air burning, a great amount of carbon in the form of coke had to be added to the "mine" for reduction in the furnace. All that would be rendered unnecessary by the adoption of the "carbousiron" process, and the valuable substances would be conserved for use. He feared he had taken up much of the time of the meeting, but he had been anxious to show that fuel oil could be obtained approximately in the quantities stated in the paper, and that the substances he had mentioned were eminently suitable for the purpose named. He had examined every system of carbonising in the country, and did not, for a moment, hesitate to say that the processes outlined in the papers were genuinely practical, and could only serve to assist the Country at a time when it sorely needed assistance.

**Mr. H. T. Burls** remarked, in reference to the large quantity

of cannel coal requisite under this scheme, that he thought the available bulk was much below the estimate advanced. He could say, but unofficially, that the Department of the Ministry dealing with the question of the production of oil from cannel coal would be willing to take any quantity of suitable material on offer, and would be able to utilise more than was likely to be obtainable. The difficulty was not that of obtaining retorts, but the "previous question" of the supply of cannel coal to charge them.

**Sir Boverton Redwood** was obviously precluded from making any reference to the action which had been or was to be taken by the Government with the object of increasing the output of mineral oils from indigenous sources. During the latter part of 1913, and early in 1914, prior to the war, he had devoted some attention to the subject of the low-temperature retorting of cannel coal, and particulars of the results then obtained, and of the conclusions then formed, might constitute a useful contribution to the discussion on the subject under consideration. At that date, with the assistance of Dr. Mollwo Perkin and Mr. Rosenplaenter, he had carried out a practical retorting test of a certain description of cannel coal (of which he had evidence that a large deposit existed) by a well-known system of low-temperature distillation, and he had satisfied himself that, from the cannel coal in question, by the process referred to, an exceptionally high yield of oil of excellent quality was obtainable.

The actual yield of crude oil was at the rate of 50 gallons per ton of cannel coal, and experiment indicated that, by suitable refining and the cracking of the heavy spirit or of the light oil, the crude oil might be expected to yield, in practical working, 14 to 15 gallons of motor-spirit, the same quantity of fuel oil, from 32 to 33 lbs. of paraffin wax, and 40 lbs. of pitch per ton of cannel coal. From the experience he gained at that time, he was convinced that, in order to obtain the best results from an oil point of view, it was essential to adopt a true low-temperature system of carbonising.

In his Presidential Address on "The Future of Oil Fuel," delivered to the Junior Institution of Engineers in December, 1913, he had pointed out that, apart from the possibility of such modification of existing methods of carbonising coal as would render an additional quantity of liquid products available for use as fuel, an increased quantity of oil-fuel could be obtained from Scotch shale, and that certain inferior descriptions of coal, at present unsuitable as fuel, might be profitably converted into liquid products by low-temperature distillation.

The expression low-temperature distillation connotes the removal

of the whole of the volatile organic matter at the lowest temperature at which the operation can be conducted within a reasonable time, and that temperature is not the same for all descriptions of bituminous minerals.

In principle, no doubt, the Scottish practice aims at the separation of the oil at a comparatively low temperature, whilst the shale is in the relatively cool upper portion of the composite retort, before the charge passes down into the highly-heated lower part, where the ammonia is obtained, but, in the writer's experience, it is impossible, with retorts of such large diameter, to apply the necessary heat to the central portion of the charge without exposing the outer portion, in contact with the retort, to an unduly high temperature, and the injurious effect of this is shown when the yield and quality of the oil obtained from cannel coal with a retort of the Scottish type are compared with the results furnished by true low-temperature retorting.

In order to get the best results, from an oil point of view, it is necessary, with external heating of the charge, that the bituminous material should be so treated that the whole of it is subjected to the minimum necessary temperature without any portion of it being over-heated.

**Mr. Hill** pointed out that the distillation of cannel and oil shales formed a considerable industry in North Staffordshire thirty or forty years ago, but it failed for financial reasons, largely owing to increasing mine-costs. The speaker was at the present moment mining a class of cannel to assist in the calcination of a low-grade ironstone, but, even although very favourably placed, the costs were very much higher than any figures given in the papers. He was familiar with the treatment of the Blackband ironstones, having spent a large part of his life amongst them. That treatment for the purposes named was by no means new. Again, the cost, with other practical difficulties, had prevented any sound commercial headway being made. At all events he could say that local proprietors were not very much enamoured with the proposals. He therefore largely agreed with Mr. Burls in hoping that the Government would not allow the question to be side-tracked into the adoption, on any large scale, of some untried process, with the certain loss of time and money, particularly in view of the urgent necessities of the day.

**Mr. A. E. M. Taylor** did not propose to refer to the delay in making use of the home supplies of oil. With a view, however, to making a start with as little further delay as possible, he would like to submit a proposal to the meeting, speaking not only on

his own behalf but on behalf of the group of gentlemen whom he represented. That group were prepared to find one-half the money required for the erection of a low-temperature retort capable of treating 1,000 tons of material a day, provided that they could obtain (1) the co-operation of the colliery owners, and (2) the sympathy of the Government authorities, enabling them to obtain the requisite priority certificates. With regard to the first proviso, he would mention that during the last three months he had been in touch with many of the leading colliery owners, and, from the promises already received from them, and from the correspondence which had passed, he thought he could rely on their sympathy and active support. With regard to the second proviso, he felt that, if it were possible to place before the Government authorities a concrete scheme, and satisfy them that it was sound, commercially, financially and in other respects, they would be almost certain to enlist Government support. He had referred intentionally to the willingness of the group he represented to find one-half the cost of the low-temperature retort, his reason being that that course would enable other parties interested in the process to come in, and so ensure the hearty co-operation and support which, in such matters, were eminently essential. In the course of preliminary investigations, he and his friends had formed the opinion that the most economical method of dealing with the new industry would be the erection of a retort capable of treating at least 1,000 tons per day. Before arriving at that conclusion, however, none of them had had the benefit of reading the paper by Mr. Cunningham Craig, and the speaker was glad to find his impressions confirmed therein. In addition to the provision of a low-temperature retort, his friends contemplated the inclusion of a refinery.

**Mr. James Todd,** whilst disclaiming any technical knowledge of the matters more directly before the meeting, had been connected with collieries in the north of England for upwards of 45 years, and felt pretty certain that financiers could not be found—at any rate in that part of England—who would put money into speculative industries like that proposed, with the Government threatening to tax them 20, 80 or 100 per cent. of the proceeds. Let the technologists induce the Government to inform the colliery people that all the waste, all the cannel, all the "jacks" and all the refuse, of which there were millions of tons in the country, now absolutely wasted, and of which the country, in its emergency, ought to be making the greatest use, could be utilised. If, instead of talking about this and the other course being impossible, the Government would follow the line just suggested, it would be seen

that nothing was impossible in this world when pluck and energy were forthcoming to undertake and to carry out practicable schemes. If the Government would promise the colliery owners that they would forego the 80 per cent. to 100 per cent. of taxation, and the 25 per cent. of income tax, pending a five-year period, so that the colliery owner might utilise the available product, both for the benefit of the nation, and with some small profit for himself, headway would be made.

**Mr. R. Bowen** said that he had read with very much pleasure the papers put before the meeting, which seemed to contain valuable information relating to the progress made by the Institution in its researches. As indicated in the papers, no time should be lost in applying the results of the work undertaken to practical uses. While from the standpoint of ruthless science the whole question had been laid bare, it appeared to him that the still more ruthless problem of £ s. d. awaited a practical solution. Once that had been achieved, there should be nothing in the way of supplying, or helping to supply, the nation's needs. It was well known that without industrial enterprise it was impossible for any nation to hold its own in the struggle for supremacy. It went without saying that the needs of the Grand Fleet were paramount, but it was almost equally important that our industrial and household requirements should be met.

He hoped to be able to show that it was in the power of the Institution, by its recommendation, to accomplish the desired ends. He contended that with a proper handling of the crude-oil problem those ends could be met. He believed that all the waste products from the distillation of coal and shale could be used in the direction indicated, with advantage not only to the fuel, but to the quality of the oil. He would not, in the presence of scientific experts, offer adverse criticisms on the points raised in the paper, but he would like to make a few remarks on the commercial utilisation of the resultant waste products. This, he contended, was the entire secret of the success of the oil industry as a whole; the money question was at the root of the business. The speaker had devoted a great deal of time and careful study to the matter and had made many hundreds of experiments in the direction indicated, which he felt entitled him to speak with confidence from a practical standpoint.

It had been suggested, particularly in relation to cannel coal, that after distillation the residues could be briquetted with advantage. A great deal of experience had been gained in regard to briquettes; their manufacture had been intimately studied,

with the result that a really good article, giving the maximum of efficiency in heating power, combustion and calorific value, had not so far been produced—at all events by the ordinary briquetting process, with the various kinds of coal that might have been employed. It therefore appeared that the question of using ordinary coal-waste was one of importance, but when the utilisation of the residues of spent coal and oil-shale was advanced, the problem was enhanced in difficulty.

In briquette manufacturing it was well known that the "cooked" coal, mixed with its binder, was simply passed into a press and submitted to pressure, single or double, as the case might be. From careful examination of the product, the fact was revealed that the outside and the centre were not homogeneous. Hence, in order to make a passable article, it became needful to compress the outside excessively, so that the centre might be sufficiently consolidated; therefore the exterior was actually made too dense to burn, whereas it should be the first to take up the combustion process; and the result was anything but a cheerful flame.

The speaker had found that of two bricks made with precisely the same mixture, one in the usual way and the other in a laminated or stratified form, the one made by the latter method yielded a perfect result and burnt admirably, because the planes of separation of the laminæ formed planes of combustion, and so produced a material structurally compacted like ordinary coal. The laminations used of course varied in thickness and number, according to the quality of the material employed. He had found that material such as shale, and residue similar in character, could be made to burn equally well, with a cheerful flame, by adopting the method of manufacture referred to. He had also taken coal, after distillation, and, by the same method, produced a first-class house-coal at a minimum cost.

There was also something to be said about the inert material in the residues. By a careful combination of the hydrocarbons and volatile constituents, first-class fuel could be produced at low cost, and by imparting to the so-called inert materials a laminated form they actually formed radiators of heat during the process of combustion, in the same way as did the bars of fireclay and asbestos in an ordinary gas stove. A fine field was opened up for an important fuel industry in connection with the distillation problem.

By the treatment of shale in the manner indicated the great bogey of desulphurisation could also be removed; the sulphur content was reduced to a minimum or to such proportions as to be well within the most exacting requirements. The method

was an exceedingly simple one and could be accomplished at a cost not worth mentioning.

There was also, of course, the question of transport, and, in view of the well-known fact that the shale products and the poorer classes of coal existed in localities distant from the great coal-mining centres, the reduced cost of local distribution would be of importance. With regard to the price to be obtained, he was advised on excellent authority by colliery owners and agents that the fuel manufactured by the process described would sell readily at 20s. per ton f.o.r., at least, thus enabling the product to enter into competition with the higher qualities of coal. If, therefore, the fuel question was one of importance, and good prices could be obtained, a fair commercial profit would accrue from the distillation processes of coal and oil shale, which, in its turn, would solve the problem of commercial utility. He would put the average price as presented in the paper, i.e. 10s. a ton, and would assume a yield of 33 gallons at 4d. per gallon. The cost of conversion, for cannel coal, would not in any case exceed 4s. a ton, the resultant fuel being first-class, suitable for almost any combustion purposes. That material would command a price of 20s. a ton f.o.r. Taking coal therefore at 10s.; distillation cost, 6s. 6d.; cost of conversion of 75 per cent. residues, 4s.; and transport and standing charges, 1s. 6d., the total would be 22s. But as resultant products there would be the 33 gallons at 4d. a gallon, equalling 11s.; 40 lbs. of ammonium sulphate at 1½d., equalling 5s., and 18 cwt. of fuel at 20s. a ton, or 18s. The total would therefore amount to 34s., leaving a net profit of 12s. per ton, sufficient to make the proposition a business one.

To obviate the difficulty consequent upon the first 50 per cent. of oil distilled from the oil shale being of better quality than the remainder, and therefore less costly to refine, he suggested that three-quarters of the oil should be distilled, only one quarter being left in to help in the fuel problem. That course would give a total cost for mining, transport and retorting of 16s. 6d., leaving a net profit of 14s. 1d. per ton, a result far better than in the case of the ordinary methods, while, in addition, there would be no "waste-tips." That surely was sufficient to warrant enterprise, and to ensure Government co-operation.

**Mr. F. Lamplough** desired to put in a word for the Government, which had once or twice been criticised that evening. Few persons, apparently, realised that their choice was between two things. Some were solicitous that everything should be put aside in favour of low-temperature distillation, but, as the aim of the

moment was the production of explosives, high-temperature distillation was essential; few explosives could be obtained from low-temperature distillation. Another difficulty was the need of metal for the building of retorts, as the available metal was required for purposes which he need not name. The object of the meeting was to discuss the best method of obtaining the largest quantity of oil from cannel coal. He had for a considerable time been working on behalf of a firm interested in that proceeding, and he had received assistance from the Royal Automobile Club and its technical staff. The results were so promising as to excel anything he had read in the papers under discussion; for example, in a test made as late as the previous Sunday as much as 80 gallons of oil had been obtained to the ton. The results were too recent to be verified at present, but the experiment was to be repeated, and he hoped that the figures would be confirmed. The cannel coal used was, of course, an exceedingly rich variety.

On the question of the method of distilling the coal, he might point out that all existing retorts, fired by external heat, were not suitable for treating cannel, if large quantities of oil were desired. He had found internal heating to be the best method, and he had worked in that direction for a number of years. It had been proposed, and in 1905 was actually tried at Essen, to distil cannel coal by means of highly heated water-gas. That gas, however, being already saturated with carbon, would not be a very suitable vehicle for carrying over the rich hydrocarbons which it was desired to extract from the cannel. He had tried the process with superheated steam, and found the vehicle to be most suitable. At certain temperatures it was very absorbent, the process was under complete control, and the apparatus required was of the simplest design. A rough trial could be carried out in an old drain-pipe, and the results, even so, would be extraordinary, probably better than with some of the most refined apparatus. It might sound absurd to use superheated steam on account of the large amount of condensation that would occur; but that could be reduced, as up to a certain temperature, approximately 300° C.—when the resinous matters began to melt and distil over, the steam could be circulated through the superheater, and back through the retort. As the residues began to dissociate themselves from the coal, the temperature could be increased, and distillation could be carried out in the condensing apparatus in the ordinary way.

In regard to retorts, he had found that the old horizontal would take 15 hours to carbonise a charge of coal, the intermittent vertical approximately 14. The best known verticals, such as the Woodall-

Duckham, would occupy 10 or 12 hours. The same work could, however, on the method he proposed, be carried out by superheated steam in something like 6 hours. External heating was attended, as many would be aware, by the further disadvantage that 50 per cent. of the time was occupied in carbonising 80 per cent. of the material, the remaining 50 per cent. of time being employed to carbonise the remaining 20 per cent. By that time the retort had almost reached incandescence, and the gases from that 20 per cent. were attenuated and destroyed, the rich hydrocarbons were converted into graphite, and it became a moot point whether they were worth taking out at all; probably the only reason for so doing was the difficulty of separating the uncarbonised material from the coke when withdrawn from the oven or retort.

He had found that a factor making for simplicity in his method was the use of direct heat. There would necessarily be great loss in transmitting heat through fire-clay retorts, and in the course of his experiments he had found that the best form of retort would lose, in the settings and through the flues, 50 per cent. of the heat employed for carbonising, that was the best result, but in some cases 75 per cent. would be lost. With the process he was trying at the present time the loss was under 10 per cent. If therefore by the ordinary method 10 tons were used to distil or carbonise 100 tons of coal, his method should reduce the figure to approximately 1 ton. Another point in favour of low-temperature distillation was the considerable reduction of the sulphur content. Again, as members would know, no such reaction took place as occurred when high-temperature distillation was employed.

At the present time, however, all forces had to be turned upon the high-temperature distillation, unless some method of building retorts without the aid of metal could be used. Upon that question he had been working from a practical standpoint, so as to enable any colliery to fit up a retort built simply of firebricks, in which coal could be carbonised in as simple a manner as bricks could be baked in a brick-field, and he did not think a more simple process could be desired. There were many details into which he was not at liberty to go, even if time had permitted, as the Government were looking into the question. He would, however, be pleased to submit full particulars to the President, if desired.

**Prof. J. Cadman** desired to make a few remarks and to preface them by expressing his confidence that there did not exist a more loyal body of men than the Institution, and that all present

desired to assist in the solution of the difficult problem under discussion. His official position precluded him from referring to the general policy that was being pursued, but he regarded the discussion as well-timed, and a discussion which really added to knowledge on the subject was and would be of vast importance.

He would like to direct attention to one or two points in the paper which, in his view, might have been expanded or enlarged, and in the first place he would refer to the history of the problem as ignored in the title of the paper. He regarded that title as unfortunate; though it perhaps betrays the enthusiasm which the authors were known to possess. Although entitled "A New British Oil Industry," the paper proceeded to deal with the very oldest oil industry, and one which originally started in this country. Cannel coal was, as its name implied, "candle" coal, and was no doubt the first coal worked in the country. Many centuries ago cannel was dug for the purpose of getting illumination when burnt in open grates. In due course it was found that an oily matter trickled out on to the hearth, and this led to the starting of what could fairly be called an oil industry long before any oil was worked in any other part of the world. In Beckman's "History of Inventions," 1798, a reference to a text-book to show that oil was worked from cannel coal was made in vol. i, p. 399, to "the burning of coals in order to procure from this a rock oil, used particularly for leather manufacture, which is much practised in England," the reference further indicating that the product must not be exported, which suggested that in those days there was a tariff on the exportation of oily material. The leather industry was at one time of paramount importance here, and the oil for that industry was extracted from cannel coal.

In a work published in Frankfort in 1683, by J. J. Becker, an interesting reference was made to the extraction of oil from coal, tested in the presence of Charles II., and stating that "the coals after this tar has been extracted from them are better for use than before." As far back as 1781 a patent was granted to the Earl of Dundonald for the right of extracting or making essential oils from pit coal, bituminous coal and cannel. In 1785 the term of 14 years was extended to 20, by special Act of Parliament. That, it would be noted, was before the introduction of gas-making, somewhere about 1802.

When the first gas-works were put up, the cannel coal, or a highly bituminous coal, was the coal naturally sought for; it had a high illuminating value, and gave considerable volumes of gas. The working of cannel coal appears thereby to have been

stimulated, and in 1846 Gesner, in his "Practical Treatise on Coal, Petroleum and other Distilled Oils," handles the subject very fully. Some quotations followed as to methods adopted for extracting oil from coals and shales, principally cannel, from which the greater portion of the oil was obtained. In a list on p. 56 Derbyshire cannel was said to give 82 gallons to the ton; Wigan cannel, 74 gallons; Liverpool cannel, 50 gallons; Poole shale, 48 gallons; Newcastle, 48 gallons; Boghead cannel, 120 gallons; Scotch cannels, 40 gallons, and Lesmahagow cannels, 96 gallons. The book also gave some very interesting comparative data as to high and low temperature, a subject on which he proposed to say a few words, because, owing to the loose manner in which the terms were used, it was not always clear what was meant by "high" and "low temperature." He might venture even to say that the authors of the papers appeared a little indefinite in the use of the terms.

Prof. Cadman quoted from the book under consideration the following results from one ton of Newcastle cannel coal distilled for gas and for oil:—

| Distilled for Gas. | | Distilled for Oils. | |
|---|---|---|---|
| Coal-gas .. .. | 7,450 cub. ft. | Gas .. | 1,400 cub. ft. |
| Tar .. .. .. | 18½ gallons | Crude oil | 68 gallons. |
| Coke .. .. .. | 1,200 lbs. | Coke .. | 1,280 lbs. |
| **Products of the Tar.** | | **Products of the Crude Oil.** | |
| Benzole .. .. | 3 pints | Eupion .. | 2 gals. |
| Coal-tar Naphtha .. .. | 3 gallons | Lamp Oil | 22·5 „ |
| Heavy oil, Naphthalin, &c. .. | 9 „ | Heavy oil & paraffin | 24 „ |
| Total .. .. | 12⅝ gallons | Total | 48·5 gals. |

(Eupion being the product now called petrol.)

It will be noted that 68 gallons of crude oil gave 48 of refined products. This was before Young's patent of 1850.

The work went on to show the various forms of retorts, a subject on which the paper might have given a little more information in place of dismissing it in a few lines; when all was said and done, the problem was greatly dependent on the forms of retorts that were used. He would offer a few quotations on this part of the subject. "If a given quality of coal be distilled in a retort or closed vessel at a heat of 1,200° F., or thereabouts, in the manner that coal-gas is made, a large quantity of gas will be formed. But if the heat to which the coal is exposed does not exceed 750° or 800° F., a different class of result follows. To obtain these

results not a little depends upon the form of retort. The retort which will permit the charge of coal to be equally heated throughout is best. On this account revolving retorts, that keep the charge in constant motion, have been introduced." Then were described the various forms of retorts, among others the ordinary D-shaped horizontal retort. Of the revolving retort it was said "that one of 6 ft. diameter and 8 ft. in length would run 6 charges, of one ton each, in 24 hours, of ordinary cannel coal." The question of vertical retorts was also dealt with, and details were given of the types of retort used in 1845. In that year the Archimedean screw was used in the retort for propelling the material in order to mix up the product and obtain more oil. It was therefore clear that the various patterns of retorts now being considered had all been carefully and deliberately worked upon more than 50 years ago, so that it was abundantly clear that the subject was not a new one, the production of oil from cannel coal was indeed a matter almost of antiquity. Of course its importance was now enormous.

He thought he might rightly enquire why cannel coal was not more abundantly used, and why we had not at the present time great industries producing oil from cannel coal. As a matter of fact, at one period of the country's history there was a considerable number of oil distilleries scattered all about. Mr. Hill had referred to one in South Staffordshire, the remains of which the speaker had seen and remembered quite well, and the details of which had been described to him by his father, who had been closely connected with the development of that centre. In those days cannel was brought from various mines to vertical retorts situated in two or three parts of North Staffordshire. The retorts, of considerable importance even in those days, were manufactured at Coalbrookdale, in Shropshire, and in the early days were carried on the backs of donkeys and mules to Staffordshire. The industry throve in Staffordshire, Shropshire, and the North of England, in those days, and it was pertinent to ask why it had not continued to thrive. The answer was, apparently, the cost of mining, which gradually became so great that the distillation of oil ceased to be profitable. Cannel itself was an erratic deposit, varying enormously in thickness and oil-value, so that it became impracticable to ensure continuous output of the product in quantities which would warrant work on a large commercial scale. Young started his important industry on cannel and bituminous coals, and his original retorts were patented for the working of that type of coal. As the cost of material increased, he sought for material which

would yield a high oil-value, and hit upon the well-known Scotch torbanite referred to in the paper. He erected retorts to work these Scotch cannel deposits. Ultimately the supply failed, and he had to turn attention to shales having uniform yield, and it was upon these materials that the Scotch industry now existed. He did not propose to deal with the other part of the history of the oil industry of this country, viz., that relating to the importation of oil and its influence on the commercial value of such enterprises, as the facts were well known.

There were one or two further points in the papers requiring attention. In referring to the Scotch shale industry, Mr. Cunningham Craig had alluded to the process as being conducted at a high temperature, whereas Dr. Mollwo Perkin had referred to the same process as being conducted at a low temperature. (**Dr. Perkins** denied this, claiming to have said an "intermediate" temperature.) At any rate there was a sufficient difference to warrant the conclusion that it would have been better had the two authors compared notes before submitting their papers. Mr. Cunningham Craig was not quite correct about the Scotch retort, which was more on the lines indicated by Dr. Mollwo Perkin; it combined both high and low temperatures. In that combination the oil was distilled at the top, at about 1,200° F., and the ammonia product was dealt with at the bottom, at about 1,800° F., both temperatures being taken outside the retorts. This process had been evolved in course of time, through long and intimate practical experience in the distillation of shales, which had commenced with cannel coal.

Mr. Hollingworth's remarks dealt with a subject with which the speaker was personally familiar, for he had seen very careful experiments conducted in relation to attempts to obtain oil from Blackband ironstones, and had himself conducted many such. He could assure Mr. Hollingworth that he was not on new ground, and not developing a new idea so far as concerned the North Staffordshire Blackband ironstone. It presented, however, one of the most important of the unsolved problems, namely, the extraction of by-products from ironstone, which was here of special interest as being one of the richest deposits in the country. The Blackbands contained approximately 50 per cent. of carbonaceous matter, and on calcination produced an extremely rich ore. Mr. Hollingworth might not, however, be aware that one of the great difficulties in calcining that product related to control of the temperature, an important factor in giving an ore comparatively free from sulphur and phosphorus, and so far as he was aware,

played an important rôle in the class of ore produced by open-air calcination. He was not for a moment suggesting that the difficulty might not be got rid of or corrected by a particular method of retorting. A laminated deposit of this kind must, if oil had to be extracted from it in a closed retort, be first broken up into small pieces; this produced a large proportion of dust, which could not possibly be used in the blast furnace without special treatment, and the difficulty to be overcome was therefore a very real one. Some 15 or 20 years ago he was connected with these ironstones and had made attempts to extract oil from them, and he might with profit narrate an incident in that connection. In experimenting with Blackband ironstones, he had used two forms of coke-oven retorts. The mass of ironstone fused into clinkers, and the retorts had to be destroyed in order to remove these residues. He got the oil all right from both retorts, but the retorts had to be pulled down to get the ironstone out. Of course that was long ago, and the speaker was then a youngster, but the circumstance illustrated the difficulties to be overcome. He could not say whether Mr. Hollingworth had got over the difficulties; he would not suggest that he had not. Before, however, the process could be introduced, it would be needful to show that the product could be treated in bulk. He trusted that Mr. Hollingworth would be successful in his venture, because, if such were the case, a most important addition would be made, not only to the iron industry, but to the oil industry of the country.

The prices referred to by Mr. Cunningham Craig appeared to him to be unreal. When that author spoke of 5s. 6d. a ton for mining the Scotch shale, it would have been well if he had made fuller enquiries into the actual cost. Mr. Cunningham Craig had taken the figure from a 1910 Blue Book, which did not indicate the present cost of production. Then his attempt to base calculations on the cost of cannel being 10s. a ton seemed to call for more investigation.

The discussion, as he had already said, was well-timed, and any views which could be brought forward to aid in the development of an industry which all present had at heart, would meet with the approval, not only of the Institution, but of the nation.

**Mr. W. H. Manfield** desired to add his testimony in support of using low-temperature distillation when dealing with shales from the Kimmeridge measures and with cannel coals. After a great number of trials with large quantities of Kimmeridge shales and some cannels, he had found that the lower the temperature used—provided it was sufficient to bring off the oil-vapours—the

higher would be the yield, and the better the quality of the oil. Any process which enabled the oil-vapours to be liberated at a lower temperature, and which assisted rapid distillation, was of great advantage.

Mr. Cunningham Craig had observed that Kimmeridge shales were not yet being worked commercially. That statement was correct, but mines were being opened up in the Kimmeridge oil-shales in Dorset and it was not at all improbable that before very long those mines would be producing very considerable amounts of motor-spirit and of oil.

**Sir Lionel Phillips** remarked that he had come to the meeting to listen to the discussion as a student. He had had something to do with preparations for the production of material from which oil might be furnished to this country. He would like in the first place to express his indebtedness to the writers of the papers for their suggestive ideas. In favour of those who were responsible for trying to effect the production of oil, might he say that those persons were by no means asleep; a good deal was being done, more, indeed, than could be spoken of at present. He must also add that there were difficulties in the way, and those should not be overlooked. Anyone familiar with mining was well aware that material could not be charmed out of the ground; a great deal of time, of patience, of material, and of labour were required. As to whether or not any undertaking of the kind was worth doing would depend, in times like the present, upon the cost and the results achieved when the work was done. Mr. Manfield had just referred to the Kimmeridge. The speaker had particularly had to do with the testing of that material for oil, but it would not be proper for him to go into that question in detail. As far as he was at present advised, however, it would take at least a year from the present time to get, say, 500 tons of oil a day from such material, and when it was obtained, what was to be done with it? At present there were difficulties which referred not so much to the extraction of the oil as to its nature when extracted. The oil was full of sulphur, a very unpleasant matter to deal with, as members would know, when the attempt was made to burn anything with which it was associated. It therefore became necessary to find some processes by which the oil could be extracted without too severe a fumigation of the people engaged in the industry. That was one point in connection with Kimmeridge shales. It was known that there were millions of tons of the material available between Dorset and Lincolnshire, in thin layers, but whether it could be used either for the purposes of war or for ordinary com-

mercial purposes in the future, was a problem that awaited solution. The speaker regretted that his friend who was responsible for the production of oil from home sources was not present; he had hoped that gentleman would have been able to attend, have read the papers, and have spoken a word or two, as far as his official position would permit. He, however, felt justified in saying, from what he knew, that his friend had been giving his very earnest attention to the whole question, and that he was on the road to provide such a practical solution as was warranted by the circumstances of the time. In a few months the speaker felt that we should witness as great a production of oil from home-produced material as the present conditions allowed.

One of the audience desiring to know in what condition the sulphur was found in the Kimmeridge shales, Sir Lionel Phillips said that the sulphur was found in a double condition. When the distillation of the shale commenced, fumes of sulphur came off, which were, of course, unpleasant to those doing the furnace work. In addition to that, sulphur was found in a chemically-combined form in the oil, and that was the difficulty to be solved in connection with the oil when it had been produced.

**Mr. Cunningham Craig,** replying to the discussion, said that Mr. Burls appeared to hold that the amount of retortable material in this country was small; that there was not, in fact, a sufficient amount available. Without directly asking Mr. Burls how he acquired his information, he (Mr. Cunningham Craig) would point out that there were various ways of acquiring information on matters of that sort. There was what might be termed "the official" way, which was to employ some official, perhaps in London, who did not necessarily know anything about the matter, to write letters to various people—managers of works or colliery owners—about the country, and perhaps send them forms to fill up. In the course of time those forms or answers to the letters would come in, the totals were added up, and they constituted the "official" information. When, however, the addition had been made, it was almost invariably wrong. Another way of securing information was to send one or two people who knew something about the subject round the country, to make enquiries for themselves, not only from managing directors, managers of mines and factories, but from all and sundry, and gather information wherever they could find it, but this was often found to yield quite different results from the "official" information. As he had said, he did not know how Mr. Burls acquired his information,

but if he had explained the method by which he procured it, the speaker could have judged what was meant by the word "available."

With regard to Prof. Cadman, it was evident that he had been reading up the subject very carefully, but, so far as the speaker could make out, the Professor's information dated chiefly from the middle of last century. He had, for instance, stated that the idea put forward was not new; it certainly was not. The idea of distilling cannels to get oil from them was not new; but there was a new idea in the distillation of cannels in the modern way, to get petrol—a new idea in itself—or to get fuel oil for any purpose for which it was wanted; or to get gas by producers, and, after all, producers were a "new idea." Prof. Cadman had stated that the industry had thriven. At that time, no doubt, the value of oil was great; it was great now. At that time there were no importations of oil in very large quantities from abroad. When that importation began and increased, no doubt, the industry languished and died out. The idea certainly was not new, but to start an industry of that kind now by modern methods was new; and that, he thought he had the right to maintain, would be a new British oil industry. He objected to Prof. Cadman's criticism of the title of the papers. The papers had been written by his colleagues, Dr. Perkin, Dr. Dunstan, Mr. Berry and himself, who had also chosen the title, which he believed they were perfectly within their rights in doing.

With regard to the observations about high and low temperature, he feared Prof. Cadman had been guilty of a quibble. There was no doubt, as pointed out by Dr. Perkin, Scottish oil shales were distilled at a lower temperature than that which would be used to make the maximum quantity of benzol or toluene from the coals, but at a much higher temperature than would be employed in what were ordinarily called low-temperature processes. In talking of high and low temperatures, the speaker judged by the nature of the oil produced. If the oil were cracked at a high temperature, with formation of a large amount of incondensable gas, that would be called high-temperature distillation, and that was what the Scotch method really was.

Prof. Cadman had mentioned that certain figures or prices were unreal. He (Mr. Cunningham Craig) had not, of course, spoken of war-time prices. What it was desired to establish was an industry that would go on, once started, in peace time, at ordinary peace-time prices. He had not considered a war-time basis, but had taken the figures as they were given, and had calculated the

cost (roughly, he admitted) on what he believed the cannels would cost to bring to bank in this country, averaging the cheap with the dear ones. He thought that if Prof. Cadman had studied the subject more carefully, and had gone about the country, and learnt the conditions in each part, he would not have suggested that the prices quoted in the papers were unreal.

In answer to Sir Lionel Phillips, he would say that he was not concerned with anything official, or the work of any official Department. The Institution of Petroleum Technologists was an intensely practical Society, and was "out" for getting things done, and to help on the doing.

The directions from which opposition to the formation of a British oil industry could be expected were well known, and it was with this view of strengthening the hands of the Government, and combating that opposition that the members of the Institution had felt bound to put their researches and the conclusions they had reached, prominently before the public, who in the last resort were the final Court of Appeal.

**Dr. Mollwo Perkin** also replied to the discussion in so far as it concerned his contribution to the papers. He said that Mr. Cunningham Craig had covered most of the points to which he would, naturally, have been inclined to draw attention. He was, however, astonished, if Prof. Cadman would excuse his saying so, to learn that the references in the papers to high and low temperature were not clear. In his allusions to high temperature, the speaker had really referred to gas practice—to a temperature of about 900° to 1,000° C. inside the retorts. By "low temperature" on the other hand, he intended to refer to a temperature inside the retorts of anything from 390° to 600° C. He would take a medium temperature to be about 800° C. inside the retorts. He believed that he had actually given those figures in the paper, except that he had referred to experiments, which he had carried out in the North of England, in distilling coal, in which a temperature of 1,400° C. was used, with a subsequent drop to about 1,100° C. (**Prof. Cadman** here pointed out that the author had quoted 450° to 550°.) Dr. Perkin, continuing, remarked that 390° C. was a lower temperature than he had been accustomed ever to use, but he quoted the figure as someone had recently expressed to him a liking for working at that temperature. On the question of the quality of the oils, the Navy and the Army, as he had mentioned in the paper, required high explosives, and he had further mentioned that the gas industry practically saved the war for the country by producing material for high explosives.

Beyond that the Navy required, as did the aeroplanes, a supply of petrol and fuel oil, involving hydrocarbons of quite a different class. Now that the gas industry was being worked to its full capacity, and the shale-oil industry also, it became necessary to put up retorts for the production of fuel oil. The fact that retorts of the required class were invented some fifty or a hundred years ago did not matter, as modern conditions were quite different to old practice; the retorts were needed, and the question just now was not whether they would be a paying proposition, but of getting what was wanted, and that could be obtained from cannel coal and from other classes of coal, such as coking coals. With cannel coal he would suggest the use of producer-plant for working up the residual coke for power gas and sulphate of ammonia. With coking coals there would be a smokeless fuel, which would be very valuable. Cannel coal contained much ash, and consequently the coke was not an ideal fuel. The public, however, would soon take to the use of a good smokeless fuel which burnt readily and could be used in ordinary open grates.

The question of cost was, of course, a very difficult matter, especially in connection with retorts. If, however, the cost of these was set against that of steamships, there was something to go upon. Steel was required for cannon and for almost everything employed in the conduct of the war—shells, rails, cannon, mine-sinkers and so on. Surely there was no desire to deplete the stock of steel to a greater extent than necessary. Indeed, it was difficult to get the Government to give permits for steel and iron. Retorts could be built with the minimum amount of those metals. To a large extent fireclay and fire-bricks could be used for the retorts. He would not go into all the points raised by the various speakers, but he desired to "rub in" the fact that the question was not one of money but of carrying on and winning the war. Even supposing the enterprise to cost two million sterling, that did not represent much more than about a quarter of what it cost each per day to run the war.

**The President** believed that all had listened to the discussion that evening with very great interest and a good deal of instruction, but so far as the main question before the meeting was concerned, namely, the economic practicability of the utilisation of cannel coal as an important source of oil production, the discussion had left the speaker with an open mind. Though the figures presented by Dr. Perkin seemed to show that, from the metal point of view, this source of oil production had everything to recommend it, there was yet no sufficiently definite evidence as to the extent of

the available supplies in any given district, nor as to the price at which colliery owners would be willing to sell it. Some of the speakers had asserted that sufficient quantities of the coal existed, others that they did not. To the speaker it appeared that this was a question that could be very easily settled, and if it could be shown, after proper examination, that there was, in any given district, a sufficient production of cannel coal to provide raw material for a satisfactory working unit, say about 2,500 tons a day, which would yield, according to the estimates given, about 100,000 tons of crude oil per annum; and if, in addition, it could be shown that the cannel coal could be produced at a cost of, say, 12s. to 15s. a ton (he had no personal knowledge of what would be a paying price to the colliery proprietor), then there was no doubt that the putting up of the necessary retorts and stills would be justified. In any case, the evidence submitted undoubtedly sufficed to constitute a *prima facie* case for the utilisation of cannel coals, and he ventured to urge the Council to recommend to the Petroleum Executive the immediate appointment of a sub-committee of competent men to investigate this many-sided question further in a reliable and practical way. There were, indeed, too many aspects to be considered without the assistance of experts acquainted with all sides of the question. Such a body, to be of any value, should be an expert one, and should, apart from representatives of the Petroleum Executive, include at least (*a*) two colliery owners acquainted with the potentialities of cannel-coal production; (*b*) two petroleum technologists; and (*c*) two commercial men acquainted with the business side of the oil industry. He would put the proposal before the Council of the Association, and he hoped they would be able to adopt his suggestion.

**The President** accepted a recommendation that the body proposed should include two engineers of experience in the carbonising of cannel coal, which was in fact intended under his term of technologists. He closed the proceedings by proposing a cordial vote of thanks to the authors of the papers for their valuable and interesting communications, which were, he added, worthy of the Institution, and fulfilled one of the chief functions in which a technical body of this kind could render services of great value to national interests.

## Twenty-ninth General Meeting.

This meeting was held at the House of the Royal Society of Arts, Adelphi, W.C. 2, on Tuesday evening, 19th March, 1918, Sir Boverton Redwood, Bart. (Vice-President), occupying the Chair.

The Members of Council present were Messrs. E. H. Cunningham Craig, Arthur W. Eastlake and T. C. Palmer.

**The Chairman** expressed his regret, which he was sure all would feel, that the President, Mr. Charles Greenway, was prevented by illness from being present to take the Chair. The lecturer, Mr. Ghambashidze, needed no introduction, in the sense that his official position was a sufficient guarantee that he came before them that evening to speak authoritatively on the subject of the paper.

The following paper was then read :—

## The Russian Petroleum Industry and its Prospects.

By D. Ghambashidze, *Hon. Secretary and Member of the Executive Council of the Russo-British Chamber of Commerce in London.*

In dealing with the Petroleum Industry in Russia we have to consider various fields of production which are chiefly concentrated in the Caucasus, on both sides of the main Caucasian Mountains, while some are situated in the Transcaspian districts.

They are the Baku, Grozni, Kuban, and Guria fields to the west of the Caspian Sea, and the Uralsk and Transcaspian fields to the east.

All these latter fields are, up to the present, of much smaller importance than Baku. Some of them are only in the experimental stage, or not yet worked to their full capacity, and will therefore only be dealt with shortly here, before we enter upon the subject of the classical and prominent field of Baku.

*Tcheleken.*—Tcheleken is a small island in the Bay of Krasnovodsk in Transcaspia, and contains some not very considerable oil areas, but some fountains were produced on it from rather shallow depths, and brought it greatly into prominence. The oil produced is mostly brought to Baku for refining; it contains a high percentage of paraffin, and leaves on treatment an unusually heavy residue of thick tar, which at ordinary temperatures is almost solid, and must be mixed with the more fluid residues of the Baku oil before it can be burnt in the usual firing appliances.

The production of crude oil from the Island was: in 1911, 15,000,000 poods: 1912, 12,000,000 poods: 1913, 7,600,000 poods: 1914, 5,000,000 poods. Other oil-fields in this district are also found on the shore of the Caspian Sea near Tchikishliar, and at about 20 versts from the Bala-Ishem Station of the Transcaspian Railway. The latter is called the Naphtha Hill, and in consequence of the shortage of fuel the Railway Company intends to build a branch line to it, and to start its exploitation.

*Fergana.*—Fergana is in the central part of Turkestan, near the Station Vanovsk on the Central Asiatic Railway. The greater part of this field belongs to Nobel Brothers, who struck the first flowing well in 1904 at a place near Chimion, and have since then increased the number of their wells to ten in 1915. The annual production varies between 1 and 2 million poods, but the whole region is being developed, and a refinery built, as well as a pipe-line to the above-named station.

*Kuban District.*—The Kuban District is situated on the north-western slope of the Caucasian Main Chain, and comprises several fields whose importance is not yet established. *Anapa* and *Taman* are two of them, whose prospecting was begun in 1912, chiefly by British capital, but no final results were arrived at before the war stopped further activities. The *Maikop* field came to the fore in 1909, when a prolific gusher broke out in it so unexpectedly that the oil was lost, as no preparations for its storage had been made. Enormous excitement followed this event. Companies were formed, speculation in land and feverish borings began on all sides. A pipe-line was laid to the Station Einem, and also two pipes to the port of Tuapse, but unfortunately the production of the field was a great disappointment, as only a few wells yielded oil, and in 1916 only five of the 66 Companies founded in London for the exploitation of this field were still working, mostly in the centre and the south-eastern part of it. It is expected that deeper drilling will give better results. The aggregate depths of all the wells drilled in 1912 amounted to 11,929 sajens, and in 1913 to 14,475 sajens, and the production of crude oil was in 1912, 9,262,118 poods: 1913, 5,344,798: 1914, 5,000,000.

*Grozni.*—The Grozni oil-fields are situated on the northern slope of the Caucasian Mountains, and are connected with the Vladicaucas railway by the Baku line. Deep boring began there in 1903, as hand-dug wells, which formerly had been utilised, were found to be quite inadequate. In fact, the important oil horizons lie very deep in this field, and most of the original wells are now down between 3,000 and 4,000 feet, and nevertheless their productivity is diminish-

ing. However, new sections have been taken up during the last few years, and are being methodically worked, specially also as concerns prevention of the flooding of the wells by surface water, which accident had repeatedly happened in the beginning of the exploitation. The total area worked in the field in 1916 was 2,861 desiatines (7,066 acres), and there were 773 wells, of which 385 were in operation. The total of the drillings executed in 1913 were 203,000 feet: in 1914, 290,000 feet: in 1915, 181,930 feet: and in 1916, 153,307 feet.

The total output of the field was: in 1911, 70,000,000 poods: 1912, 65,000,000: 1913, 70,000,000: 1914, 98,455,000: 1915, 88,165,000: 1916, 102,727,615: 1917, 9,198,000 (during January only). A great part of the Grozni oil is exported through the port of Novorossisk. The quantities shipped from there were: in 1910, 170,609 tons: in 1911, 234,285: 1912, 213,186: 1913, 219,480: 1914, 149,330. The closing of the Dardanelles stopped further exports, and as the Grozni oil is specially suitable for the production of high-class benzine, the consequence was that enormous quantities of it are accumulating in the field.

*Ural-Caspian and Djingi.*—These fields cover a large area on the north-eastern shore of the Caspian Sea, the two principal centres of production being Dos-Sor in the Emba district and Novobogatinsk. The former district is in a rather unfavourable position as far as drinking water is concerned, and the crude oil produced contains a somewhat high percentage of sulphur. The operations began in 1912, and in 1915 the number of wells amounted to about 60. The production of the Ural districts was as follows: in 1912, 1,014,825 poods: 1913, 7,181,776: 1914, 16,630,985: 1915, 16,620,724: 1916, 15,649,000.

*Djingi* is a new field on the west of the Ural river, extending northward from the shore of the Caspian Sea. The prospects are believed to be very favourable, and several wells sunk by Nobel Brothers have given satisfactory results. The situation of all these fields so near the Volga makes their great importance for the Russian home trade obvious.

*Guria.*—This oil-field is situated in the district of Ozurgeti, at a distance of 25 miles from Batum, and only 5 miles from the small ports of Supsa and Nicolas on the Black Sea.

Natural outflows of petroleum had been known there for a long time, but only in 1911 a Baku firm made a trial boring which produced a flowing well at a depth of only 63 feet. This immediately caused a great rush to take up lands in the neighbourhood; experts were sent to the spot and several British and other Companies

formed. Drilling was started in 1913 in three places, but the outbreak of the war interrupted the work.

The research will, no doubt, be taken up again as soon as circumstances permit, as the exceptionally favourable position of this field practically on the Black Sea coast makes it specially interesting.

*Baku.*—After these few remarks on the comparatively minor Russian oil-fields, we now come to Baku, which to-day is still the all-important centre of the Russian oil industry. The principal objects of this paper will be to consider the present situation of the industry, and to give the latest available statistical data and information, but it will omit the technical side of the business, as the members of this Institution are of course fully acquainted with this special part of the subject. The following remarks will therefore deal only with the economic aspect of the industry, which, while of the highest importance to the trade in general, is perhaps less of the domain of the technical expert.

I. *Production of Crude Oil.*—Before 1870 all the crude petroleum was obtained from surface pits, dug by hand, and rarely more than 50 feet deep. In that year boring according to the American system was first tried, and a hole was drilled to a depth of 20 sajens, but had then to be abandoned. However, this new system was further employed and with better success, and we find in 1872 two boreholes in operation; in 1873, 13; in 1874, 26; in 1875, 35; in 1872, 62; and in 1887, even 216. Although in those days the diameter of the tubing was very small, boring proved very profitable, as in many cases the new wells produced from 3,000 to 10,000 poods of oil in twenty-four hours. But these successes of the boring operations also had quite adverse economic results, for the desire for fountains became so fascinating that most of the producers feverishly tried to drill as deep as possible, leaving the upper strata unexploited, and then the abundance of fountains resulted in many cases in the actual loss of oil and damage to neighbouring properties. Also, there was occasionally an over-production of crude oil, with consequent fall of prices.

In 1873, Robert Nobel arrived on the scene in Baku, and to his enterprise and technical genius a great deal of the subsequent rapid development of the industry is due. This development and general awakening of enterprise is best reflected by the number of boreholes in operation during the periods mentioned, as follows: 1893, 458: 1894, 532: 1895, 604: 1896, 734: 1897, 917: 1898, 1,107: 1899, 1,357: 1900, 1,710: 1901, 2,036: 1902, 1,967: 1903, 1,982: 1904, 2,171: 1905, 2,162: 1906, 2,149: 1907, 2,511: 1908, 2,668: 1909,

2,818: 1910, 2,026: 1911, 3,065: 1912, 2,412: 1913, 2,670: 1914, 2,541.

The aggregate depths of drilling executed during each year of the same period were: 1893, 10,986 sajens: 1894, 12,859: 1895, 20,762: 1896, 28,125: 1897, 39,847: 1898, 57,515: 1899, 81,832: 1900, 83,140: 1901, 75,783: 1902, 40,390: 1903, 49,355: 1904, 62,354: 1905, 35,666: 1906, 48,110: 1907, 61,253: 1908, 56,793: 1909, 51,803: 1910, 48,436: 1911, 44,864: 1912, 52,554: 1913, 64,285: 1914, 51,086: 1915, not recorded: 1916, 4,300.

A comparison of the yearly drillings with the corresponding productions shows, as it was to be expected, that in order to maintain and increase the production, the wells had to be sunk to greater and greater depths. In 1910, of all the producing wells, 385 were at a depth of from 250 to 300 sajens, 117 from 300 to 350, and 27 of over 350 sajens. Of course, at such depths boring operations are very slow and expensive. A well costs 100,000 to 150,000 roubles, and cannot be finished in less than two or two and a half years. The enormous falling-off in the drilling during 1916 is accounted for by the difficulty of obtaining the requisite materials and tools, and their enormous price.

The production of petroleum in Russia since the beginning of this century was as follows (in millions of poods): 1901, 707·2: 1902, 672·5: 1903, 631·1: 1904, 657·1: 1905, 453·1: 1906, 490: 1907, 518: 1908, 528: 1909, 531: 1910, 582: 1911, 557: 1912, 566·6: 1913, 559: 1914, 557: 1915, 572: 1916, 603: 1917, 584 (estimated).

The number of firms engaged in the production during the same period was: 1901, 185: 1902, 182: 1903, 185: 1904, 179: 1905, 169: 1906, 170: 1907, 189: 1908, 185: 1909, 192: 1910, 198: 1911, 191. These figures are fairly stationary, and the firms in question can conveniently be divided according to their relative importance into five groups, viz.:

(1) 7 firms with an average yearly production of over 20 million poods each;
(2) 5 of over 10 million;
(3) 11 from 5 to 10 million;
(4) 20 of from 2 to 5 million; and
(5) 135 less than 2 million poods each.

From the middle of the year 1912 a very serious process of concentration of the large and middle-sized producing firms began, and towards the end of 1913 the following grouping ensued:

I. The Shell Group, including: The Caspian and Black Sea Co., Soutchastniki, Kavkas and Schibaieff, produced 50·8 million

poods, or 11·8 % of the total production of the four older Baku fields and Surakhani.

II. General Russian Corporation, including: Aramasd, Balakhany Co., Apsheron Co., Quarnstrem, Grassilnikoff Successors, Lianosoff, Mantacheff, Mansuetoff, Moscow-Caucasian Co., Naftalan Co., A. C. Melikoff, Melikoff & Makhmuroff, Tiflis Co., and Shikhovo Co. This group produced 55·1 million poods, or 12·8 % of the total output.

III. Nobel Brothers produced 61·2 million poods, or 14·2 % of the total output.

IV. The 165 remaining firms, each working separately, produced 253 million poods, or 58·8 % of the total.

As shown above, the first three groups produced 41·2 % of the total output of the Caucasus, and if they should unite, they would not only control the production, but also the sale of the products. So far no signs of trusts have appeared yet, although there are many cases of joint contracts being entered into. In order to show the relative importance of the different Russian fields, I give the following rough figures of their output during 1915-6 (in millions of poods):

| | 1915. | 1916. | | 1915. | 1916. |
|---|---|---|---|---|---|
| Baku ... ... | 451 | 379 | Maikop ... ... | 8 | 8 |
| Grozni ... ... | 88 | 102 | Emba ... ... | 17 | 15 |
| Tcheleken ... | 3 | 3 | Fergana ... | 2 | 2 |

The most recent figures of the average daily production in Baku are

| 1915. | 1916. | 1917, Jan.-Feb. | 1917, March. |
|---|---|---|---|
| 940,000 | 906,000 | 803,000 | 758,000 poods. |

The prices of crude oil in Baku were (in kopeks per pood):

| | 1906. | 1907. | 1908. | 1909. | 1910. | 1911. | 1912. |
|---|---|---|---|---|---|---|---|
| January ... | 18·1 | 23 | 24·6 | 19·2 | 18·55 | 14·14 | 28·4 |
| February ... | 22·2 | 24·4 | 25·6 | 20 | 18·65 | 15·47 | 31·0 |
| March ... | 24 | 25·2 | 26 | 21·6 | 17·48 | 16·8 | 34·4 |
| April ... | 23·9 | 25·3 | 24 | 21·3 | 16 | 17·43 | 32·7 |
| May ... | 23·5 | 28·6 | 23·2 | 21·2 | 15·1 | 18 | 34·56 |
| June ... | 24·2 | 27·4 | 22 | 21·7 | 14·9 | 20·1 | 35·9 |
| July ... | 25·5 | 28·3 | 20·9 | 21·9 | 14·4 | 22·5 | 35·6 |
| August ... | 26·7 | 28·5 | 21·1 | 21·5 | 14·3 | 24·76 | 36·35 |
| September .. | 26·7 | 29 | 21·2 | 20·9 | 14 | 26 | 36·2 |
| October ... | 24 | 25·4 | 20·9 | 19·4 | 14 | 22·75 | 36 |
| November... | 22.3 | 24·5 | 19·4 | 19·6 | 14 | 22·12 | 36·5 |
| December... | 22·6 | 24·9 | 18·9 | 18·5 | 13·8 | 23·58 | 37·0 |
| Average... | 23·8 | 26·7 | 22·5 | 20·5 | 15·43 | 20·65 | 34·55 |

| | 1913. | 1914. | 1915. | 1916. | 1917. | 1918. |
|---|---|---|---|---|---|---|
| January ... | 37·5 | 30 | 30·2 | 48·6 | 45 | 96 |
| February ... | 37·5 | 27·75 | 28·5 | 46 | 55 | 96 |
| March ... | 37·9 | 41·5 | 37·6 | 45 | 61 | — |
| April ... | 39·5 | 38·1 | 41·3 | 45 | 65 | — |
| May ... | 39·4 | 35·1 | 41·5 | 45 | 65 | — |
| June ... | 40·4 | 44·7 | 41·25 | 49 | 60 | — |
| July ... | 45·6 | 47·3 | 47 | 45 | 60 | — |
| August ... | 52·9 | 42·5 | 47·1 | 45 | 60 | — |
| September | 53·0 | 39·5 | 41 | 45 | 60 | — |
| October ... | 46·6 | 29·4 | 41·6 | 45 | 96 | — |
| November | 43·9 | 24 | 44·6 | 45 | 96 | — |
| December... | 38·6 | 28·3 | 53·2 | 45 | 96 | — |
| Average ... | 42·7 | 35·7 | 41·2 | 45·7 | 68 | 96 |

As these figures show, the prices of the crude oil vary considerably from causes which can mostly not be controlled by the producers. But in a general manner these variations do not much affect the trade, and if in any year the market is low, the deficiency will soon be recovered, as happened, for instance, in the years 1910 and 1911. Since March, 1916, the prices have been officially fixed by the Government, but this legal maximum is not maintained in practice, and a premium of 19½ kopeks per pood was, for instance, paid in February, 1917, and this increased to 29 kopeks per pood above the official figure in March of the same year.

In normal times the profits on the sale of the crude oil fluctuate between 13 and 18 %, so that the business is quite profitable. The percentage varies according to the strength of the firm in question; the big houses are of course better able to protect themselves against expected market fluctuations, and to secure favourable conditions by acting together. Such was the case in 1910, when the price of masut in Baku was from 32 to 35 kopeks per pood, while in Moscow it reached 60 kopeks. This figure forced the factories in that district to abandon oil fuel, and fall back upon coal, the price of which was then 18 kopeks per pood.

II. *Refining.*—The first illuminating oil produced in Baku was distilled from the oil-impregnated sand, called "Kir," from which some 15 to 20 % of oil were extracted in 1860. The process used was very defective, and there was no regular market for the product, so that the enterprise collapsed.

A new era started with the visit of the celebrated Professor Mendeleeff, who suggested many improvements in the technics of

the distillation and refining of the products. Many other chemists also worked at the solution of the numerous problems connected with the industry; crude oil was introduced in place of the oil sand as raw material, the use of sulphuric acid was begun in the refining process, and slowly the product was improved and brought nearer to the standard of the American kerosene.

In 1872 there were in the Baku district about 57 distilleries, but their business was most irregular, and work was often suspended, so that they produced only about 2,400 poods of kerosene and 2,860 poods of lubricating oil. At first the distillation had been effected by means of small retorts or closed vessels, which had to be reopened after each operation, thus causing a great loss of time and fuel. In 1875 a continuous system was patented, which was then improved by Nobel, and by which alone the production could have reached its present enormous figures. In 1876 the number of refineries established in Baku amounted to 140. They were mostly erected in the centre of the town, or near it, and made it nearly uninhabitable by their smoke and refuse, which flowed into the streets and the harbour. A special district was therefore selected, to which all had to remove, and which forms now what is properly called "The Black Town."

One of the great difficulties of the industry in its beginning had been the necessity of sulphuric acid, which had to be brought from Europe at great expense. In 1883 Nobels built a factory for its production on the spot from Caucasian pyrites, mined in the neighbourhood of Alexandropol, and other factories for the same purposes and for the regeneration of the acids have since then been established. The installation of the present great number of refineries has also in its turn given rise to a multitude of other auxiliary mechanical and industrial works.

Officially the refineries are divided into three categories according to their products, viz:—(1) kerosene; (2) benzine and goudron, and (3) lubricating masut. It is difficult to draw a strict line between them, but the relative numbers in all Russia were:

| | 1893. | 1894. | 1895. | 1896. | 1897. | 1898. | 1899. | 1900. |
|---|---|---|---|---|---|---|---|---|
| Cat. 1. | 95 | 92 | 92 | 95 | 95 | 98 | 75 | 80 |
| „ 2. | 23 | 19 | 22 | 27 | 20 | 19 | 20 | 17 |
| „ 3. | 59 | 54 | 55 | 50 | 46 | 58 | 50 | 40 |
| Total | 177 | 165 | 169 | 172 | 161 | 175 | 145 | 137 |

In 1897 there was a decrease in the number of refineries, owing to the liquidation of the Union of Refiners, and to other conditions

of the industry. At first kerosene was the principal product of the refineries, and was exported abroad in large quantities, while the residues of the distillation were burnt, with their valuable constituents. Only later the latter were also extracted, to the great advantage of the factories, and now they form a valuable source of profit.

The following list shows the proportion of factories producing chiefly the various substances:

| | 1906. | 1907. | 1908. | 1909. | 1910. | 1911. | 1912. |
|---|---|---|---|---|---|---|---|
| kerosene ... | 59 | 59 | 54 | 54 | 43 | 39 | 10 |
| lubricant ... | 17 | 17 | 19 | 17 | 16 | 14 | 9 |
| solar oil ... | 2 | 2 | 3 | 3 | 3 | 3 | 1 |
| benzine ... | 1 | 1 | 2 | 2 | 2 | 2 | 3 |
| residues ... | 5 | 6 | 6 | 7 | 6 | 5 | 3 |
| paraffin ... | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| | 85 | 86 | 85 | 84 | 71 | 64 | 28 |

Nearly all the petroleum produced in the Caucasus is refined in that region. The refineries existing in Nijni-Novgorod, Moscow, Petrograd and Riga, distil only about 10 or 12 million poods per annum.

In calculating the cost of the refining operations we have to take into consideration as a basis the cost of the crude oil delivered at the refinery, the fuel, for which often the residues of the distillation are used, the cost of chemicals, administration and labour and general expenses.

The following table shows the lowest and the highest prices (in kopeks per pood) of kerosene in Baku delivered in tank-cars on railway or f.o.b. the steamers in the port, for the years mentioned:

| | In Tank-cars. | F.o.b. Steamers. |
|---|---|---|
| 1906 ... ... ... | 23·6—39·2 | 21 —41 |
| 1907 ... ... ... | 26·7—43·1 | 26·8 —44·3 |
| 1908 ... ... ... | 24·9—30·7 | 24·6 —34·2 |
| 1909 ... ... ... | 24·4—32 | 23·9 —32 |
| 1910 ... ... ... | 17 —28·5 | 15·7 —28 |
| 1911 ... ... ... | 19 —34·1 | 18·66—33·58 |

As an indication of the propositions of the various articles produced by the Baku refineries, we give herewith the list for April, 1916. Their total production amounted to 23,848,900 poods, composed as follows:

| | | |
|---|---|---|
| Illuminating oils (kerosene, pyro-naphtha and astral oil) ... ... | 5,874,900 | poods. |
| Lubricating oils (spindle, machine, cylinder, vaseline, viscosine) ... | 980,500 | ,, |
| Solar oils, light and heavy ... ... | 514,000 | ,, |
| Benzine ... ... ... ... | 101,300 | ,, |
| Naphtha residues ... ... ... | 13,585,000 | ,, |
| Paraffin ... ... ... ... | 6,800 | ,, |
| Other products (gasoline, goudron, oil residues, lubricating masut, etc.) ... | 2,786,400 | ,, |

III. *Transport.*—In the early stages of the industry the transport conditions were very primitive. The crude oil was carried from the wells in skins and barrels loaded on carts or camels, and Nobels were the first to lay a pipe-line to their factory. Later on pipes were laid between the factories and the port. These obvious improvements met in the beginning with fierce resistance from the workpeople. The transport of the finished products to the consumers was equally difficult. There was then no railway from Baku to Tiflis, and the only way to the Black Sea was thus shut off. On the other side the navigation on the Volga was only possible during six months of the year, and the monopoly of the Steamship Companies Mercur and Kavkas on the Caspian Sea imposed high rates on the Baku products. Improvements were again due to the Nobels, who built the first cistern wagons for transporting the oil on the railways, instead of using wooden barrels, which were often unsatisfactory.

In order to open an outlet on the Black Sea, Nobel Brothers constructed in 1889 a pipe-line from Mikhailovo to Kvirili over the Suram Mountain, which forms the most difficult part of the railway between Baku and Batum. The transport by the railway, which was now available, was very unsatisfactory, principally owing to the configuration of the country, as the line was often flooded, which caused interruptions of the traffic for weeks and even months at a time. The idea of replacing it by a pipe-line for the transport of the oil was therefore natural, and a project had already been formed in 1882. But its execution met with great delays, and the western part of it, from Mikhailovo to Batum, was only ready in 1890, while the portion from Baku to Mikhailovo began to work only in 1906. The whole length of the pipe-line from Baku to Batum is about 560 miles, and requires 19 pumping stations. The diameter of the pipe is 8 in., and it has a capacity of 60 million poods per year. Its cost was 25 million roubles.

The quantities of oil thus transported were:—In 1900, 21,490 thousand poods: 1901, 59,162: 1902, 56,495: 1903, 52,780: 1904,

64,695: 1905, 19,543: 1906, 21,760: 1907, 26,570: 1908, 27,674: 1909, 19,788: 1910, 26,425: 1911, 23,630: 1912, 22,000.

Since the closing of the Dardanelles the pipe-line has been partly idle, and was then used for the transport of kerosene distillate for fuel, and even for crude oil. The charge for pumping oil from Baku to Batum was 13 kopeks per pood, while the railway charged 16 kopeks per pood on oil to be exported, and 26 kopeks per pood for that destined for consumption in Russia.

While this pipe-line is now more than sufficient for the transport of the Baku products to the Black Sea, the trade has at its disposal on the Caspian Sea a considerable number of steamers and sailing vessels adapted for it, as the following list shows:

| | No. of Steamers. | Capacity Cub. ft. | No. of Sailers. | Capacity Cub. ft. |
|---|---|---|---|---|
| 1906 | 131 | 5,294,774 | 140 | 2,886,841 |
| 1907 | 129 | 5,230,246 | 144 | 2,792,719 |
| 1908 | 129 | 5,225,100 | 142 | 2,764,849 |
| 1909 | 127 | 5,200,245 | 145 | 2,846,982 |
| 1910 | 120 | 5,239,409 | 150 | 2,993,653 |
| 1911 | 121 | 5,011,191 | 147 | 2,899,687 |
| 1912 | 118 | 5,518,664 | 60 | 1,755,034 |

In 1912 the transport of petroleum products formed 37 % of the whole traffic on the Volga, and 5 % of the total traffic on all the Russian railways. The means of transport used at present for the Baku products are shown by the quantities forwarded during April, 1916:

| | | |
|---|---|---|
| By Transcaucasian Railway... ... | 2,553,200 | poods. |
| „ „ „ to Batum | 1,019,500 | „ |
| „ Vladicaucas Railway ... ... | 531,700 | „ |
| „ Sea to Astrakhan... ... ... | 43,818,500 | „ |
| „ „ Petrovsk ... ... ... | 304,900 | „ |
| „ Transcaucasia ... ... ... | 773,700 | „ |
| „ Persia ... ... ... ... | 247,600 | „ |
| „ Other ports ... ... ... | 421,000 | „ |
| Total | 49,670,100 | poods. |

Of the other producing centres Grozni sends a part of its crude oil to the refineries in Novorossisk, whence the light oils are exported, while the residues, which amount to about 16 million poods per year, are pumped to Petrovsk on the Caspian Sea by pipe-line, and there shipped by steamer to Astrakhan and Central Russia. The Maikop production goes for refining mostly to Ekaterinodar, and is consumed locally.

IV. *Distribution.*—(1.) Home Market.—This market is of the highest importance to the Baku industry, and even more so to the whole country, as heating and lighting materials are generally scarce, and especially coal, which is indispensable in many industries, labours under great and chronic difficulties of transport. As the export trade has considerably diminished, specially since 1905, and in consequence of the American competition, the home market has easily absorbed by far the greatest part of the production, and the consumption can only increase in the future as new manufactures will be created in the country.

For this reason the Government had in 1916 worked out a plan for the distribution of the available illuminating oil, which is estimated at 60,392,000 poods. Of this quantity the following apportionment between May, 1917, and May, 1918, was:

| | | |
|---|---|---|
| The Railways | 5,394,000 | poods. |
| Petrograd District | 7,798,000 | ,, |
| Petrograd Central | 10,640,000 | ,, |
| Southern District | 8,115,000 | ,, |
| Volga ,, | 4,450,000 | ,, |
| Kieff ,, | 5,313,000 | ,, |
| Odessa ,, | 2,556,000 | ,, |
| Rostoff ,, | 5,105,000 | ,, |
| Caucasus ,, | 2,370,000 | ,, |
| Ural ,, | 2,003,000 | ,, |
| Siberia ,, | 2,816,000 | ,, |
| East Siberia ,, | 563,000 | ,, |
| Far Eastern ,, | 277,000 | ,, |
| Turkestan ,, | 2,943,000 | ,, |

Only 6½ million poods can be directly transported by water to the centres of consumption, while 40 million poods will be carried by sea to the Volga ports, there to be reloaded on the railways, and the rest will be carried by railway only direct from the factories to the consumers.

As to fuel oil, even much larger quantities have in the last few years been shipped to the Volga ports for distribution in the interior of Russia, viz.: 1913, 77,035,100 poods; 1914, 75,024,200; 1915, 102,799,400. The great increase of 1915 is due to the disturbance of the coal production by the war, and the urgent necessity of obtaining fuel from other sources. The consumption of the immediate neighbourhood of the producing centres is in itself not inconsiderable. Baku, for instance, uses from 10 % to 15 % of its production of crude oil as fuel, although this quantity is gradually decreasing, as electric energy and fuel-

saving engines are being introduced. The whole of the Caucasus, and especially the Transcaucasian Railway, used in 1912 15,000,000 poods, and the Vladicaucas Railway 17,000,000.

The home trade in kerosene is in Russia subject to Government Control, and to an Excise Duty, of which more will be said later. The storage of the oil coming from the factories has given rise to quite an important Government control, thus:

| | 1901. | 1902. | 1903. | 1904. | 1905. | 1906. | |
|---|---|---|---|---|---|---|---|
| No. of Storages | 71 | 64 | 69 | 60 | 69 | | |
| „ „ Reservoirs | 340 | 290 | 327 | 255 | 365 | | |
| Quantities stored | 38,681 | 44,928 | 43,828 | 30,087 | 53,354 | | pds. |

The relative proportion of the various petroleum products in Russia was as follows:

| | Kerosene. | Lubricating. | Solar. | Residues. | Others. | Total. |
|---|---|---|---|---|---|---|
| 1901 | 135,631 | 16,788 | 537 | 329,364 | 1,951 | 484,071 |
| 1902 | 128,150 | 16,984 | 1,280 | 383,136 | 2,870 | 512,414 |
| 1903 | 154,921 | 19,984 | 3,821 | 324,436 | 2,736 | 564,898 |
| 1904 | 162,150 | 19,800 | 3,050 | 330,665 | 1,937 | 517,692 |
| 1905 | 80,509 | 13,584 | 2,037 | 292,656 | 1,860 | 390,646 |

The stocks held in Baku on January 1st of the respective years (in poods):

| | 1912. | 1913. | 1914. | 1915. |
|---|---|---|---|---|
| Crude... ... | 15,174,212 | 21,254,634 | 17,338.297 | 30,000,000 |
| Residues ... | 29,824,676 | 31,163,920 | 25,358,896 | 41,886,800 |
| Illuminating... | 8,196,998 | 10,149,010 | 9,157,302 | 11,209,600 |
| Lubricating ... | 2,008,878 | 2,130,061 | 2,131,730 | 2,070,600 |
| Benzine ... | 311,606 | 890,607 | 1,056,899 | 1,523,200 |
| Solar Oils, etc. | 2,129,368 | 2,233,015 | 2,084,949 | 1,960,300 |
| | 57,645,738 | 67,821,247 | 57,128,073 | 88,650,500 |

(2) Export Trade.—It may seem strange that the products of the Baku petroleum industry should, from the very beginning, have been almost exclusively utilised for the export trade, and not for the home consumption. One of the chief reasons for this anomaly was the fact that Baku was far distant from the chief distributing centres of the Empire, and had practically no railway connection with them. Also, the Government was fostering the export trade from its initial stages. It released the export goods from the Excise Duty, and even encouraged the exporters by a special export premium of 4%. The export for foreign countries was chiefly concentrated in the Black Sea port of Batum, whence the goods were shipped to the countries of Western Europe, Africa and the Far East. The

export through the Caspian Sea to Persia was of comparatively small importance.

The Transcaucasian Railway and the pipe-line to Batum were really the makers of this export trade, and at the same time gave to the port of Batum a considerable increase of activity and importance. About 100 huge tanks were erected there for storing the oil brought from Baku by rail and by the pipe-line. Then about 10 special factories were started for the manufacture of tin cans and wooden cases, which, in the beginning, were the usual mode of packing of the oil for export, each case containing usually 2 cans of 4 gallons each of petroleum. This packing required a great deal of work, and occupied a great number of men and important installations of modern machinery. Rothschild's factory, which was installed in 1892, was the most important, and could produce and fill 36,000 tins per day, and pack them into the respective wooden cases. This factory occupied about 1,400 hands, and had 28 iron tanks of its own. The export of such cases from Batum amounted to 2,276,512 cases in 1910, and to 1,400,000 cases in 1912. Two-thirds of the entire export of the port of Batum consisted of petroleum products, and the port had no competition to fear from the other Black Sea ports, as for instance to the port of Novorossisk, the railway tariff on petroleum products was $7\frac{1}{4}$ kopeks higher than on the Transcaucasian Railway. But from the beginning, the Baku exporters had to face the American competition on the foreign markets, and this, after some time, became too strong for them, as they were not organised. Nobel Brothers attempted to unite the representatives of the industry, but their attempt failed, as everybody was suspicious. The firm of Rothschild adopted a different attitude. They entered into contracts with various producers, and accepted their products for sale on commission. In October, 1893, the Government summoned a conference of Baku industrials to Petrograd. This was attended by men representing 60 % of the entire industry, and they endeavoured to combine the organisation of export. An agreement was reached, and Nobel Brothers and Rothschild were appointed as representatives for the interests of all the exporters. The same firms were also empowered to enter into an agreement with the Standard Oil Company for the purpose of dividing the world's markets, which agreement came into force on February 19th, 1894. In March of the same year the Transcaucasian Railway lowered its tariff from 19 kopeks to 14 kopeks per pood, and in July further to 9 kopeks per pood. This measure had a most beneficial effect, and increased the exports. But the Union did

not live long, and was wound up on October 1st, 1897. The Baku industrials had unfortunately failed to understand their interests, and to follow the lead of such up-to-date firms as Nobel Brothers and Rothschild.

During the above epoch the chief product of export was illuminating oil, and it was principally directed to Turkey, Egypt, Persia, India, Indo-China, China and Japan. The following amounts are (in millions of poods):

| | 1893. | 1894. | 1895. | 1896. | 1897. | 1898. | 1899. | 1900. |
|---|---|---|---|---|---|---|---|---|
| To Europe ... | 22 | 20 | 22 | 19 | 18 | 23 | 30 | 32 |
| To the Far East | 28 | 23 | 29 | 33 | 34 | 33 | 39 | 43 |
| Eastward percentage ... | 56 | 55·5 | 57 | 63·4 | 65·4 | 60 | 56·5 | 57·3 |

In spite of this activity the export trade was not properly organised, as the Baku industry had no direct connection with the various markets, and had to rely upon intermediaries and dealers, who had the trade in their hands both in Europe and abroad. The lack of a commercial fleet under the Russian flag was also a great disadvantage, as it enabled the foreign buyers to profit by the freights. Practically the entire export was then in the hands of the big firms like Nobel and Rothschild, who controlled it in their own interests. The export of petroleum products through all ports and Custom houses of the Empire was as follows (in thousands of poods): 1901, 18,227: 1902, 91,237: 1903, 95,528: 1904, 119,115: 1905, 51,988: 1906, 47,941: 1907, 44,792: 1908, 50,281: 1909, 48,512. The total exports from Baku alone amounted to in 1913, 371: 1914, 322: 1915, 385: 1916, 409 millions of poods.

The total of 1916 comprises the following details: kerosene, 61,900,000 poods: lubricating oil, 7,500,000: residues, 271,800,000: crude oil, 63,700,000: solar oil, 1,900,000: benzine, 1,100,000: other products, 900,000: total, 408,800,000 poods. Of these quantities there were forwarded by sea to Russia and Persia, 366,400,000 poods: by rail to Russia, 38,400,000: by road, 4,100,000. The consumption of all products of the industry in home and export trades is approximately as follows, in million poods and percentages:

| | | | |
|---|---|---|---|
| 1. | As fuel in Baku district ... ... ... | 100 | or 18·5 % |
| 2. | „ „ on railways ... ... ... ... | 120 | „ 22·2 % |
| | „ „ in industries (including 80 million poods burnt in internal-combustion engines) ... ... ... ... | 120 | „ 22·2 % |
| | „ „ by Caspian and Volga Steamers ... | 60 | „ 11·1 % |
| 3. | „ „ illuminating oil in Russia ... ... | 75 | „ 13·9 % |
| | „ „ „ „ exported abroad ... | 30 | „ 5·5 % |
| 4 | „ lubricating oil in Russia ... ... ... | 7 | „ 1·3 % |
| | „ „ „ exported abroad ... ... | 13 | „ 2·4 % |
| 5. | „ other products (chiefly benzine) in Russia | 5 | „ 1·0 % |
| | „ „ „ exported abroad ... ... | 10 | „ 1·9 % |
| | | 540 | „ 100 % |

There is a marked decline in the export figures since 1905, which coincides with the troubles in Baku, although these difficulties were not the principal cause of it. The exports to England, France, Holland, Belgium and Germany had declined considerably, but of decisive importance was the loss of the Indian, Chinese and Japanese markets, which had absorbed nearly 70% of the whole exports. The decline of the export had a very damaging effect on the development of the industry, and more particularly on that of the port of Batum, as it coincided with the gradual introduction of the tank-steamers, which to a great extent superseded the former mode of shipment in cases. Most of the case factories had to be closed, and the workmen dismissed. At the same time the receipts of the Transcaucasian Railway and of the pipe-line diminished in proportion with the traffic, and the latter specially had to content itself now with only a small proportion of the transport for which it had been built.

(3) American and other Foreign Competition.—In the early sixties the first cargo of American kerosene was imported into Russia, about 100,000 poods, and this caused more attention to be paid to the production of Baku. In 1872 the imports had already increased to about 1,630,000 poods, and from this time America became the most serious competitor with Russia. The particularly favourable geographical position of Pennsylvania, being connected with the Atlantic by a net of railways and pipe-lines, and having direct connection with the commercial centres of the world, and its own fleet, had a great deal to do with this success.

While the freight from New York to Kronstadt was about 30 kopeks per pood, it amounted to 35 kopeks for the journey from

Baku to Nijni-Novgorod. The American industry had also at its disposal great and cheap credit facilities, which was not the case in Baku, and added to this, Baku had to pay excise duty to the Government long before the goods were sold—in short, there were no restrictions on the trade in the United States, whilst the Government regulations in Russia were very onerous.

Also, owing to its chemical composition, and to better methods of refining, the Pennsylvanian petroleum gave 75% of illuminating oils, while that of Baku only contained 33%, so that, altogether, the two industries had to develop under diametrically opposite conditions. The effect of these combined facilities showed itself in the production, which in Texas, Louisiana, Indiana, Kansas and California reached 260 million poods in 1901, 485 in 1903, and 761 in 1905.

Further serious competition then arose also in other directions. In the early nineties petroleum began to be produced in Galicia and Rumania, and these two countries soon squeezed the Russian product out of the German and Austrian markets. An industry also sprung up in the Dutch Indies and in Burma, and supplied the vast Eastern market which had been of such great importance to Baku.

For comparison of the recent and present relative importance of the principal producing countries, the following table shows production in barrels of 42 gallons:

| | 1914. | 1915. | 1916. | 1917 (estimated). |
|---|---|---|---|---|
| United States .. | 265,762,533 | 281,104,104 | 300,767,158 | 341,800,000 |
| Russia .. .. | 67,020,522 | 68,548,062 | 72,801,116 | 70,000,000 |
| Mexico .. .. | 21,188,427 | 32,910,508 | 39,817,402 | 60,000,000 |
| Dutch East Indies .. | 12,826,579 | 12,386,808 | 13,174,399 | 14,500,000 |
| Rumania .. .. | 12,705,208 | 12,029,913 | 10,298,208 | 11,000,000 |
| Galicia .. .. | 5,033,350 | 4,158,899 | 6,461,766 | 5,000,000 |

V. *Labour.*—Towards the close of the nineteenth century, the industrial district of Baku became a great centre of accumulation of labour. Workmen came to that city from four different sources: from the Volga district, where it is the usual thing for the peasants to go for extra earnings during the autumn and winter months; from the Transcaspian district; from Persia, where there is an abundance of very cheap labour, and from the Caucasus. According to nationalities they may be divided into Russians, Tartars, Armenians, Persians, etc. There is a great difference in these various elements, in the way of their productivity, standard of life and traditions, and whilst such a mixture makes them difficult to handle, there is on the other hand an advantage in this point that it has taken them a long time to unite. Until 1903 there were

practically no strikes in the district, but in that year, when strikes occurred all over Russia, partly for political and partly for economic reasons, Baku was prominent in this movement.

It must here be mentioned that the difficulty of the labour movement in Russia, especially as far as it affects the interests of industry, has always had the following peculiar basis, that whilst in Western Europe, like Germany, Austria, France, Great Britain and America, strikes have chiefly been organised by the Trade Unions, and for economic reasons, in Russia, labour strikes have always been promoted and utilised by Socialistic parties for political reasons, at least as long as there were no Trade Unions in the country. Consequently in all the strike movements the police immediately interfered, not recognising either economic or political reasons, and considering strikes as an unlawful method of activity. This interference, with few exceptions, was a factor rather aggravating than improving the relationship between masters and men, very often prolonging the strikes and causing even bloodshed. Such interference on the part of the police was without exception looked upon unfavourably by the masters, who preferred to deal themselves with the strikes of their men. The Armenian-Tartar massacre of 1904, in conjunction with the revolution of 1905, endangered the position of the industry enormously, and the Government absolutely failed to arrive at a satisfactory settlement. In 1906 the first attempts were made to organise Trade Unions in the Baku district, and considering the very difficult situation, they have been rather helpful in ameliorating the unhealthy state of affairs. A special Council of the Petroleum Industrials also actively assisted in settling the labour question, and at a special conference with the Ministry of Commerce and Industry in Petrograd a labour delegation from Baku was invited to participate, and present their views of labour. As far as the economic grievances of the working men go, they had not much to complain of, compared with other industrial districts of Russia, as a considerable reduction of working hours, and increased wages, were introduced.

One of the most ridiculous demands of the workmen was the so-called "nagradnya" (bonus), which had unfortunately been introduced by some firms which made good profits. In consequence, all the workmen began to demand it, not caring about the crisis through which the industry was passing. The ignorance of the leaders of the men was appalling. Had they been acquainted with the condition of the industry, and with the fact that foreign competition had nearly stopped the export trade, they would not have embarrassed the capitalists with the strikes, thus adding to

their difficulties, and killing the goose that laid the golden eggs. It must be mentioned here that the Council of Petroleum Industrials had constructed very up-to-date and healthy places of amusement for the workers, and that the hospitals provided for them were established on quite modern lines and exceptional in the whole of Russia.

Unfortunately, as already mentioned, one of the chief difficulties in dealing with labour has always been the clashing of political and economic aspirations, and it may confidently be hoped that after this war one of the reasons, especially political, will be disposed of, and that properly-organised Trade Unions, with a better understanding between masters and men, will be possible.

In 1913 the number of workmen and officials directly engaged in the Petroleum Industry in the Caucasus was about 60,000, out of which about 46,000 were connected with the Baku fields, viz., 42,105 in the production, and 3,925 in the refineries, pipe-lines and docks. In the Grozni district there were about 7,200 men engaged in the production, and 372 in the refineries, total 7,572. Maikop occupied 1,270 men in the production, and 74 in the refineries, total 1,344. The refineries in Novorossisk employed about 134 men, and the pumping station in Batum 363.

According to nationalities the workmen were divided as follows: Tartars and Persians, 21,488, or 54·3 %: Russians, 9,123, or 23·1 %: Armenians, 7,704, or 19·4 %: Georgians, 1,236, or 3·2 %.

According to occupations the relative numbers work out in the following proportion: administration, 6·6 %: foremen, 14·3 %: mechanics, 4·2 %: skilled workmen, 36·9 %: unskilled labourers, 27·8 %: apprentices, 1·0 %: other workers, 9·2 %.

In Baku itself the numbers of men employed in the Oil Industry amounted to 46,439 on September 1st, 1915, and to 48,526 on September 1st, 1916.

The latter were distributed in the different branches as follows: petroleum production, 31,199: boring, 8,812: mechanical workshops, 3,714: refining, 4,801: total, 48,526 men.

In 1909 the 8 hours working-day was introduced for the men working at the wells, and 9 hours for those in the shops. Housing is provided for 71 % of all the officials and workmen by their employers; 22 % of them are paid lodging-money, while the remaining 7 % are not specially provided for.

In 1910, on account of the crisis, about 27 % of the men lost their occupations, but in 1912, with the renewal of the industry, their number increased again, and kept on increasing until 1914.

Wages were increased by 20–25 % in 1913 after the strikes, and since the war began, have been further advanced very considerably.

VI. *Association of Petroleum Industrials.*—The petroleum industrials of Baku, Grozni and Maikop are organised in several associations for protecting the interests of their industry. The most important of them is the Baku Association, founded in 1889. Originally its functions were very modest, but at present it has grown into a very important organisation. In 1914 its budget amounted to Rbl. 2,704,875. The following were the items of its expenditure:

| | | |
|---|---|---|
| 1. | For medical aid ... ... ... ... | Rbl. 860,000 |
| 2. | „ education ... ... ... ... | „ 248,000 |
| 3. | „ road construction ... ... ... | „ 131,000 |
| 4. | „ collection of statistics and publications | „ 70,000 |
| 5. | „ collection and sale of oil otherwise lost on the roads... ... ... ... | „ 57,000 |
| 6. | „ drainage and lighting ... ... ... | „ 52,000 |
| 7. | „ maintenance of the police force ... | „ 587,000 |

The income of the Association is derived from the following sources: the basis is a payment of ½ kopek per pood of crude oil produced in the whole district, which, for the convenience of levying, is divided as follows:—

| | | |
|---|---|---|
| For each pood delivered to the pumping station | 0·29 | kopek. |
| „ „ „ pumped to the refineries ... | 0·06 | „ |
| „ „ „ of petroleum pumped from Bibi-Eibat to the refineries ... | 0·35 | „ |
| „ „ „ of crude oil transported from Bibi-Eibat ... ... ... | 0·50 | „ |
| „ „ „ of crude oil transported from refineries ... ... ... | 0·15 | „ |
| „ „ „ of kerosene transported from refineries ... ... ... | 0·2625 | „ |
| „ „ „ of residue and goudron ... | 0·13125 | „ |

An important revenue is also obtained from the sale of oil collected on the roadways which would otherwise be lost and a nuisance; the amount realised from this source amounted in 1914 to as much as Rbl. 459,000. Substantial sums were also derived from payments for medical assistance given to people not directly connected with the industry.

Membership of the Association is restricted to those engaged in the production, refining and pumping of the petroleum. In order to have voting power at the general meetings the firms must have a production of petroleum of 100,000 to 500,000 poods, refining 100,000 to 200,000 poods, or pumping from 1 to 2 million poods per

annum. One additional vote is allowed in case the production is over 1 million, refining over 400,000, or pumping over 4 million poods per annum. A further additional vote is granted in case of the production being over 2 million poods, refining over 800,000 poods, or pumping over 8 million poods.

The Council of the Association is composed of nine members, elected for a period of three years. Their work is honorary and consists of supervising, but the actual management is confined to the Executive Council, which is composed of the Chairman, of the representative of the Council with the Government, of the Financial Adviser, and three members—one of them managing the medical, the second the technical, and the third the educational departments. The Department of Medical Aid includes: six ambulances, apothecaries, two hospitals with 440 beds, 40 doctors, 120 midwives, nurses, dispensers and other staff, and 252 servants. In 1914 the hospitals recorded 412,660 visits; 23,609 patients were visited by doctors at their homes. The Educational Department of the Association maintains 9 schools with 57 branches, 79 teachers and 2,386 pupils. The children of the workmen are taught gratuitously, and besides this four large libraries are maintained for the men themselves. Altogether the work of the Association is very beneficial for the industry and for those engaged in it.

VII. *Ownership of Land.*—(1) Crown Properties.—With the abolition of the Concession System and the Crown administration in 1872, and with the admission of private initiative, the real development of the industry was made possible. At the time of the winding-up of the Concession system the Baku industrial area consisted of 480 desiatines (1,296 acres). The area was divided into 48 groups of 10 desiatines (27 acres) each. 46 groups were offered for auction to private people, and only two groups were reserved, being subject to litigation between the Crown and private persons. The 46 groups realised at the auction a total of 552,221 roubles. Outside of this area there were still some Crown properties for which claims were given until 1896 for 10 roubles per desiatine, and after 1896 for 100 roubles. In 1892 a special Law was issued regulating Crown properties. They were divided into two categories, those for investigation, those already proved. In 1896 an additional 70 desiatines (188 acres) were put up to auction. The system of auctions became very popular and at the times announced for them there was always great liveliness and speculation in Baku. From 1896 to 1906 Crown lands were also obtained without auction, but against royalty, which very often amounted to 40% of the gross production.

Between 1896 and 1911, 1,212 desiatines (572 acres) were disposed of without auction; 38 desiatines of them against a special tax per pood of oil produced, and 176 desiatines against royalty. In 1912, the Crown lands under exploitation amounted to about 395 desiatines (1,066 acres). In May, 1913, further auctions were held, but their results were not confirmed by the Government. Those held in May, 1914, were more successful and an area of 152 desiatines (410 acres) was handed over to the lessees under varying conditions.

(2) PRIVATE PROPERTIES.—As far as oil lands in private ownership are concerned, they are usually exploited on the basis of royalties varying between 25 and 30 %. With the decrease of the export business, the necessity for increasing the exploited area has much diminished, the more so as many other plots outside of Baku have been taken up for exploitation, and it is certain that the Baku industry will not experience any land-hunger for a considerable time to come.

In 1914 there were in the Baku area under exploitation 1,003 square desiatines, 968 square sajens (2,709 acres) of petroliferous lands, composed as follows:

(1) Private property, 324 desiatines, 2,093 square sajens (876 acres) = 32·4 %.

(2) Crown lands leased on royalty basis on the gross production: 416 desiatines, 895 square sajens (1,126 acres) = 41·5 %.

(3) Crown lands leased for a rent of 100 roubles per desiatine: 178 desiatines, 144 square sajens (481 acres) = 17·8 %.

(4) Crown lands leased for a flat rent of 125,000 roubles: 66 desiatines, 1,995 square sajens (180 acres) = 6·7 %.

(5) Crown and communal lands leased from the peasants: 16 desiatines, 234 square sajens (46 acres) = 1·6 %.

VII. *The Petroleum Industry as a source of income to the State.*—From 1821 to 1825 the Baku field was given by the State as a Concession for a yearly payment of 131,000 roubles, but as this also included the right of exploitation of the Salt Lakes the income from the oil was only 92,000 roubles per annum. In the year 1825 the State exploited the field on its own account, and obtained a profit of 76,000 roubles. From 1826-1834 the Concession system was again introduced, with a maximum annual payment of 97,000 roubles. From 1835-1850 the State began the exploitation again on its own account, with a maximum annual income of 125,000 roubles. From 1850-1867 the Concession system was again introduced, with a maximum annual payment of 162,000 roubles. From 1867-1872 the same system was continued with a payment of 186,000 roubles.

It is interesting to note that during the whole period between 1821 and 1872, only the very negligible quantity of 21,000,000 poods of oil was produced. In 1867 it was recognised that the Concession system was very unsatisfactory, and a special commission was appointed by the Viceroy of the Caucasus in Tiflis to make recommendations. The Commission condemned the Concession system, and recommended the introduction of excise duties on kerosene. With this object in view special regulations were made which came into force in 1873. It was decided to transfer the Crown properties for exploitation by a system of auctions equally open to Russian subjects and to foreigners, the leases to be for a maximum of 24 years. At the same time a special excise duty was introduced to be levied according to the capacity of the distilling apparatus used, at the rate of 4 kopeks per each vedro (2·7 gallons) for every day while the still was in operation. But for various technical reasons these excise regulations were not very beneficial to the industry, and necessitated further improvements.

In 1875 the Minister of Finance, in agreement with the Viceroy of the Caucasus, appointed a special Commission for the working-out of new regulations in place of the existing ones. The new regulations recommended a discount or drawback of 15 kopeks for every pood exported abroad, fixed as a minimum capacity for refining 75 vedros (202 gallons), and lowered the excise per vedro to three kopeks. It freed from excise the lubricating oils obtained from petroleum, and the non-refined residues, also goudron and illuminating gas. It also introduced a measure allowing the payment of the excise during twelve months, fixing the financial year from November to November of each year. Under the same regulation also made, the State also imposed a considerably higher import duty on foreign kerosene, which had also to be paid in gold. These regulations entered into force in 1877, and considerably improved the conditions of the industry, so that in 1887 the Minister of Finance, in considering new sources of income for the State, found it possible to increase the excise on kerosene, in this way getting a special annual revenue of 7 million roubles out of it per year. This latter measure, which came into force in 1888, made a distinction between light and heavy kerosene, the former taken at the specific gravity of 0·730–0·830 with a flashpoint below 45° Celsius, and the latter of a specific gravity of 0·830–0·885, and a flashpoint of 45° Celsius. The excise was fixed for the former at 40 kopeks, and for the latter at 30 kopeks per pood. All other products of petroleum, especially crude oil, were

left free from any duty. The exported kerosene for abroad was already free from excise. The only drawback imposed by these regulations was that the kerosene with a flashpoint at a temperature below 28° C. was considered dangerously inflammable, and the authorities had to prohibit its sale. Otherwise the industry was quite free from Government interference, having not even to pay the trade licences. The result of the regulations for the State were even better than expected, as in 1888 about 6,601,722 roubles were collected, or about 32 % more than the expected 5,000,000 roubles. But, as very often happens, the Government regulations were taken on the line of least resistance, and in 1891 the production of heavy kerosene considerably exceeded that of light kerosene, so that the Minister of Finance had to introduce a new classification, and the specific-gravity limit was fixed at 0·890, instead of at 0·885. Also all oil products with a flashing-point below 80° Celsius were now classified with the heavy illuminating oils and subjected to an excise duty of 30 kopeks. All illuminating oils with a specific gravity below 0·845 had to pay at the higher rate of 40 kopeks per pood. At the same time the excise for illuminating oils from kerosene was fixed at 60 kopeks per pood, and for light ones at 50 kopeks per pood. For 1916 the excise on illuminating oil was further increased to 90 kopeks per pood. The revenue from the excise amounted to: 1893, 16,369·2 thousand roubles: 1894, 18,928·7: 1895, 19,788·1: 1896, 20,925·6: 1897, 22,807·3: 1898, 23,452·5: 1899, 26,184·4: 1900, 25,503·3: 1901, 28,617·3: 1902, 29,597·9: 1903, 31,890·7: 1903, 34,688·3: 1904, 34,890: 1905, 30,003·1: 1910, 46,910: 1911, 42,488: 1912, 50,038: 1913, 48,593: 1914, 54,950: 1915, 62,040: 1916, 82,040.

The considerable falling-off in the revenue of the year 1905 is easily explained by the grave disturbances which took place in Baku in that year and the consequent necessity for extending the time limit for the payment of the excise for several years instead of 12 months.

In 1906 new excise regulations were introduced. It was decided to levy 60 kopeks per pood on all transparent oil products. Great objections were raised to this increase by the Baku industrials, who argued that such a regulation forced them to concentrate only on the production of crude oil, which would be detrimental to the healthy development of the whole industry. But these objections failed to impress the Government, all the more so as the excise was coming in in increasing abundance. It must be mentioned that, considering the bureaucratic system under which Russia was struggling to develop her industries, the State had no ground to

complain about the income derived from the petroleum industry, and the Russian capitalists, as well as any other capitalists, would have been only too delighted to give to the State its due, if only the industry was given its chance.

In 1914 the Government, under the stress of war, made a project of receiving the duty in kind, instead of in cash, and to use the oil thus received for the purposes of the Navy and other public administrations. There was also question of the installation of a Government refinery in Baku, but these projects have so far not materialised. In March, 1917, the Government decided to impose also an excise duty of 5 kopeks per pood on crude oil, which formerly had always been free.

IX. *Participation of Foreign Capital.*—In the development of the Russian Oil Industry foreign capital plays a prominent part. The first important foreign enterprise, that of Nobel Brothers, was founded in 1872 with a capital of 3 million roubles, which was increased in 1881 by 3 million roubles, in 1882 by a further 4 millions, and in 1883 again by 5 millions, thus making a capital of 15 million roubles, and showing the sudden expansion of this business concern. On the other hand, the oldest Russian enterprise, the Bakinskoie Nephtiannoie Obsh., founded in 1874, with a capital of 7½ million roubles, had to write it down to 2 millions in 1894, and only the help of French money brought it again up to about 8 millions. Russian capitalists kept strangely aloof from this industry, even after the railway to Batum had been built and had opened up the prospect of a great export business. Its possibilities were soon recognised by the Rothschilds of Paris, who founded in 1883 the Caspian Black Sea Co., and in 1898 the Masut Co., which was later bought up by the Shell Company.

The following table, from the "Nephtiannoie Dielo," shows the movements in the capital of the older companies:

| | Year of Foundation. | Original Capital. | Capital 1915. |
|---|---|---|---|
| **Foreign Capital—** | | | |
| Baku Petroleum Co.... | 1874 | 2·00 | 7·7 million rbl. |
| Nobel Brothers ... | 1879 | 3·00 | 30·00 „ „ |
| Ragozin ... ... | 1880 | 3·50 | 1·80 „ „ |
| Caspian Black Sea Co. | 1883 | 1·50 | 10·00 „ „ |
| Schibaieff ... ... | 1884 | 1·50 | 6·50 „ „ |
| Russian Naphtha Co. | 1884 | 2·00 | 24·75 „ „ |
| **Russian Capital—** | | | |
| Mirzoeff ... ... | 1886 | 2·14 | 3·21 „ „ |
| Caspian Co. ... ... | 1887 | 1·50 | 10·00 „ „ |

Therefore, while the foreign enterprises increased their capital by 66·84 million roubles, the Russian Companies only added 9·57 million roubles to theirs.

British capital became specially interested in the Russian oil industry after 1898, and between that year and 1903, 85·72 million roubles were invested in it from this source; the most important enterprises being the Schibaeff Petroleum Co., the Russian Petroleum Co., and the Baku Russian Co. The new fields, like Grozni, are almost entirely controlled by British and French capital.

X. *Prospects of the Industry.*—The present deplorable political and economic situation in Russia does not permit any speculations as to the near future of the Petroleum Industry, although the conditions in the Caucasus are far more satisfactory than in other parts of Russia. But there are still great difficulties to be surmounted, and everything depends on the outcome of the present war. The question of a State monopoly of fuel oil has lately been brought forward again, in the first instance for the necessities of the State during the war. Special committees would be given powers concerning the supervision and distribution of the oil, and on the other hand the producers in Baku and elsewhere would receive from the War Industrial Committee a certain quantity of iron and materials, the scarcity of which is now hampering production. In a general manner we must consider it premature, under the primitive economic conditions of Russia, to speak about monopolies in that country, as such systems can only be recommended to countries where the industrial development is at its full height. Russia, with its wealth of undeveloped resources, can only reckon on quick development by giving full chance to private initiative and enterprise, and it is fairly certain that this view will prevail when the political situation is settled, and when the future economic position comes to be considered. The State can then confidently rely upon getting much larger sources of income by giving full swing to private initiative, than by monopolies which everywhere kill enterprise.

As far as the future participation of foreign capital goes, it may be confidently hoped that it will always be welcome. At the same time it must be mentioned that during the war there has been a great accumulation of capital in Russia, some of which will find its way into the oil industry. But a great amount of new installations and technical improvements will have to be provided from abroad, and this will offer great and fruitful opportunities to British finance and enterprise. The expected general development and expanse of industry in the whole of Russia will cause an ever-increasing demand for oil, and this will give new impetus to the production

and to the opening-up and exploitation of new fields. It must be mentioned in conclusion that this vast industry, with its enormous resources and its undoubtedly splendid outlook, is one of those assets which will help Russia in her future clearing-off of her huge foreign indebtedness, accumulated during the present world-struggle.

COMPARISON OF RUSSIAN AND BRITISH WEIGHTS AND MEASURES.

| | | | |
|---|---|---|---|
| 1 Pood | ... | ... | 36·11 lbs. |
| 1 Ton | ... | ... | 62·03 poods. |
| 1 Sajen | ... | ... | 7 feet. |
| 1 Verst | ... | ... | 1166 yards. |
| 1 Desiatine | ... | ... | 2·7 acres. |
| 1 Square Sajen | | ... | 5·44 square yards. |
| 1 Vedro | ... | ... | 2·7 gallons. |

## *DISCUSSION.*

**The Chairman** said the paper was unquestionably a most valuable statistical record, eminently worthy of being rendered available for future reference by inclusion in the Journal of the Institution of Petroleum Technologists. He was sure that the Institution might be congratulated, therefore, in having induced so eminent an authority as Mr. Ghambashidze to enlighten them on the subject, for he spoke with the fullest information, and his statements might be accepted unquestioningly. They all realised the exceeding difficulty with which the author found himself confronted in dealing with the subject of the future of the Russian petroleum industry, in view of the obvious uncertainty of the factors. But however gloomy might be the prospects at the present time—and that gloom had not been dispelled by the very interesting remarks which the author had made as an addendum to his paper in introducing the final section, on the prospects for the future—he was, personally, optimistic enough to believe confidently in the ultimate regeneration of Russia, and the active development of the petroleum industry of that country under independent control and as a source of national revenue. Ever since he had paid his first visit to Baku, now more years ago than he cared to think of, he had been deeply impressed with the industrial potentialities of that vast country, and he could not bring himself to conceive it possible that those industries would, as the result of a so-called peace, be placed permanently under the control of any other nation.

He was well aware that that was a sanguine view to take ; it was a view which needed a great deal of faith, a great deal of hope, and perhaps, in the light of recent events he ought also to add that it needed a great deal of a third virtue, namely, charity, to accept it, and he could hardly anticipate that it would be generally accepted. Nevertheless, it was a comforting view, and on the whole it had a great deal to support it.

**Mr. C. B. Rosenplaenter** said he naturally took a special interest in the paper as he happened to be working in Baku during one of the most critical periods of the whole industry, namely in 1885 and 1886. At that time the industry was practically going to ruin, and if it had not been for the timely arrival of the Rothschilds in 1886 he did not know what would have happened. The workmen, with the exception of Nobel's, were left unpaid for five or six months. From that period onwards, however, it appeared that the Government began to realise that the wonderful organisation, which had been established throughout the Russian Empire by Nobel for the distribution of oil, gave them a right to impose an import duty high enough to prevent foreign oil from injuring the industry. He believed that this was the starting point of the prosperity of the oil industry in Baku, from which it had reached its present high position. In a way Baku had been a classical battlefield. Mismanagement by a benighted Government, doing its utmost to strangle the industry in endeavouring to squeeze revenue out of it, the unexampled disunion among the producers, and their reluctance to adopt modern methods, everything was working plainly for the destruction of the industry at one time, and that it had survived and prospered in spite of all, was not only due to Nobels and Rothschilds, but also to the intelligence and perseverance of numerous members of other races, Armenians and Tartars, who were at Baku thrown into competition in a manner no other oilfield in the world has witnessed. Among them were men who would have made their mark in the United States, as they have done in their own country, men like Mantasheff, Budagoff, Lianosoff, Tagieff, Asadulaeff and Musanagieff, who were just as much founders and creators of the Baku oil industry as Nobel, and whose fight was not so much with labour as with the Government. That the industry had survived and prospered showed the innate strength of Baku as a world producer. One could only speculate, but he hoped that a more liberal and enlightened Government would enable the industry to resume and maintain its proper place in the future.

There were a few remarks he would like to offer, not as criticisms,

but as emendations. At Grozni hand-dug wells were abolished, and fountains brought in by drilled wells in 1893, not 1903.

The author stated that, in 1872, there were two boreholes at Baku "in operation"; he presumed this meant "producing boreholes." (**Mr. Ghambashidze** assented.) In 1877, 130, and in 1894, 400 were producing oil.

Then the author had stated that many of the new wells in that period produced from 3,000 to 10,000 poods daily, but he could have truthfully said tons, as, while he was at Baku, several wells were producing many thousands of tons a day. In 1885 and 1886 wells yielding less than 2,000 poods a day were not considered worth exploiting.

With regard to the depth of the drilled wells, in 1884 the average depth was from 90 to 110 sajens. After 1886 greater depths began to be exploited.

The price of crude oil in 1885 was 1¾ kopeks a pood delivered at the refineries, and unrefined kerosene was sold at 2 kopeks a pood, whilst the residues also fetched 2 kopeks a pood. With refined kerosene at 2½ kopeks a pood, they had to make a profit, and this was accomplished, as the cost of refining was brought down to ⅛th of a kopek a pood. Benzine had no value at all, and had to be burnt at the end of the week.

With regard to the three classes of products of the refineries, kerosene, benzine and goudron, and lubricating mazut, were they to understand that goudron was the ordinary fuel-oil, and the lubricating mazut the residue after the ordinary lubricant had been removed? (**Mr. Ghambashidze** replied to both questions in the affirmative.)

It might also be mentioned that the pipe-line laid over the Caucasus was for the transportation of refined kerosene only, and not for crude oil, and he did not believe it had been yet used for any other purpose. With regard to the large consumption of crude oil as fuel in the fields (10 to 15 per cent.) this percentage had been considerably reduced during the last years. He thought the figure of 7½ to 8 per cent. of Baku's production of crude oil, used as fuel, would be right now, as large economies had been effected by the utilisation of casing-head gas as fuel, or for the production of electric power, which is now applied to quite a considerable extent on the fields.

The exportation figure for 1916, quoted on page 173 as 53,000,000 poods, must surely be a mistake, as only applicable to pre-war times. (**Mr. Ghambashidze** remarked that this was the figure for Odessa.)

On the Chairman's invitation, **Mr. R. J. Ward,** who had recently returned from Russia, said he was interested in the fuel question mentioned by the author of the paper. Very recently, as Mr. Rosenplaenter had stated, it had been decreased to a great extent by the introduction of motors. It had one drawback. They had reduced their consumption, and the local Tartar firms had also noticed the advantage, but not understanding it, more oil had been lost through fire caused by their ignorance of working. The central station for electricity was of course a great advantage in addition, its only disadvantage being general stoppages through breakdowns. Steam was quite old-fashioned, but after all, it was the most reliable.

**Mr. Ghambashidze,** in reply, said he was very much interested in Mr. Rosenplaenter's remarks concerning the intelligence of the local races in fostering the development of the industry. He had not made particular mention of that, for a certain reason, those "highly intelligent" gentlemen were doing work in certain directions which were not very favourable to our cause, because it was exactly those gentlemen who had been mentioned who had been so prominent in the industry in Baku who were also developing the Pan-Islam movement together with Turkey.

In regard to the losses which Mr. Ward had mentioned on account of stoppages, there were lots of irregularities in the Baku industry, chiefly caused by the different standard of education of the working classes. That would never be abolished unless a standardised education were introduced, and schools promoted where the working men would have to pass certain examinations and answer certain requirements, and that was practically impossible in Baku, chiefly because the men were composed of various races, and secondly because political disturbances and interference in the local industry aggravated the situation. One found gentlemen making speeches at the factories, stopping the work and addressing the workmen on an absolutely ridiculous subject, like, for instance, "the Agrarian Question in the Island of Sicily, and its bearing upon the Development of the Proletariat Movement in Buenos Ayres," and the working men had to stand in the open air and listen to that rigmarole. None of those gentlemen who came to address them understood the needs of the industry, and therefore they were aggravating the situation.

So far as the statistical side of the industry went, it had been better organised than in many other parts of Russia. He thought that would be admitted. They had an experienced staff of statisticians there, but the industry altogether needed more refining and

more disinfection in order to make it quite European and up-to-date, and that would only be possible later on when there was more education.

In his paper he had pursued the object of touching as many points as possible, because each one could be dealt with exhaustively, but that would be impossible in a single paper. The more important subjects could be dealt with separately on future occasions.

**The Chairman** said he was sure it was the pleasure of the members to record a most cordial vote of thanks to Mr. Ghambashidze for the very interesting and instructive paper which he had given them.

The vote of thanks was carried by acclamation.

**Mr. R. J. Ward** subsequently made a further communication, mentioning the extension of workable area in the Baku fields by the filling-up of the Ramani Lake and of part of Bibi Eibat Bay, and the influence of low price for product in the earlier years of the industry in inducing neglect of minor yields, and of the importance of shutting off water, of which a very heavy percentage is now raised with the oil.

The free-fall percussion system of drilling prevails, with initial diameter of 44 inches when a depth of 2,000 ft. is contemplated. The rotary system was used in the spring of 1917 to reach a flow of oil at 3,000 ft. in old ground, and, besides the great difference in speed of perforation, the smaller diameter tends, by conservation of gas-pressure, to prolong the "life" of the well and of the field. These are important factors in the future prospects of the Russian petroleum industry.